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NEW CRINOIDS FROM UPPER PENNSYLVANIAN AND LOWER PERMIAN ROCKS OF OKLAHOMA, KANSAS, AND NEBRASKA

RAYMOND C. MOORE

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INTRODUCTION

This paper is one of a series devoted to study of Late Paleozoic crinoids of North America, prepared partly in collaboration with Frederick B. Plummer, of the University of Texas. It is increasingly evident that this group of invertebrate fossils, long neglected, offers promise of usefulness in stratigraphic paleontology that is comparable to the value of ammonoids, fusulinids, and some other assemblages.

The Upper Carboniferous and Permian crinoids present many interesting problems of classification, biologic significance of morphologic characters, evolutionary trends, and ecologic relationships, but consideration of these matters is secondary at this time to the aim of learning what kinds of crinoids occur in each rock layer where they can be discovered. It is important to know exactly the stratigraphic distribution of the specimens studied, and there are few regions in the world that give such good opportunity for precise determination of the sequence of many crinoid-bearing strata as in the midcontinent region of the United States. No succession of Upper Carboniferous deposits in other parts of North America or in other continents surpasses that of Kansas and neighboring states, including Texas,

as a standard section showing the typical nature of shallow sea faunas from oldest to youngest in this part of geologic time. The occurrence of well preserved land floras at several horizons, intercalated in the succession of marine deposits, adds greatly to the value of the midcontinent section as a standard for comparison, but even more important is evidence of physical and paleontologic boundaries that define series and provide a basis for stratigraphic partition in major segments that is thought to be even worldwide in significance. The Lower Permian section of the northern midcontinent region contains many fossiliferous marine stratigraphic units, but Texas offers a much more complete succession of fossiliferous marine strata of Permian age.

Occurrence of Upper Carboniferous and Permian Crinoids

Outside of the midcontinent region, only a few rather widely scattered occurrences of Paleozoic crinoids younger than Lower Carboniferous have yet been made known in North America. This certainly indicates an inequality of effort in collecting crinoids, at least partly, for in the years before 1938 about as many species of Pennsylvanian crinoids have been described from localities in North America outside of the midcontinent area as from within it. From specimens found in Illinois and Indiana, 33 species have been described; in Ohio, 2 species; in West Virginia and Pennsylvania, 1 species; in Utah, 1 species; in Alaska, 1 species; total 38 species. From specimens collected at Kansas City, Mo., 23 species have been described, and from other places in the midcontinent region, 20 species; total 43 species. Such data do not supply information as to the number of individual specimens, collecting localities, or source beds, but they furnish approximate indication of the distribution of crinoidal material that had received attention by previous workers.

The Pennsylvanian crinoids of Illinois and Indiana come from about a dozen localities, all of which represent horizons in the Des Moines and Missouri series, but numerous additional localities are included in a list of collections not yet studied. The Ohio specimens were obtained from Pottsville (Des Moines) strata at a well known locality in Hocking County. Conemaugh beds

(Missouri series) near Wheeling, W. Va., and Pittsburgh, Pa., have yielded a half-dozen cups of one species of crinoid. Utah and Alaska are each represented by a described species of Pennsylvanian crinoid. Many undescribed crinoids from beds of Des Moines age in Colorado and New Mexico have been gathered.

Crinoid crowns, dorsal cups, and fragmentary remains, coming from Pennsylvanian strata in the midcontinent region, have been collected from some 300 localities, and each of the major stratigraphic divisions from oldest to youngest is found to contain these fossils. The Morrow series is characterized by a distinctive crinoid fauna, partly described (Moore and Plummer, 1938); the 20 species, belonging to 12 genera, and 15 types of fragmentary crinoidal remains that have been made known, come from northwestern Arkansas, northeastern Oklahoma, southern Oklahoma, and the Llano district of central Texas. Several kinds of Morrow crinoids, not yet published, are known. The Des Moines series contains a rich and interesting crinoid fauna that is represented by collections from Texas, Oklahoma, Kansas, and Missouri; 32 new species, assigned to 19 genera, from beds of Des Moines age in Texas are described in a paper now in press (Moore and Plummer, 1939). Including described but unpublished forms, the Des Moines crinoid fauna contains about 60 species, including 17 microcrinoids from Missouri, Illinois and Indiana. The Missouri series appears to contain more abundant crinoids than any other division of the Pennsylvanian rocks in the midcontinent region. The numerous species described from Kansas City belong here, and a rough estimate indicates that our present collection contains upwards of 2,000 specimens of dorsal cups from Missouri strata. Excepting work on new Missouri crinoid species from Texas (14 genera, 37 species) this material has been studied only in preliminary manner. With addition of the new Texas forms, the list of Missouri crinoids includes 27 genera and 85 species[1]. The Virgil series has yielded far fewer crinoids (9

[1] Two papers by H. L. Strimple (see bibliography at end of this paper) published after my manuscript was sent to the editor, contain descriptions of 19 additional new species and one fragmentary form from Missouri beds of northeastern Oklahoma and southern Kansas.

genera, 14 species) than underlying parts of the Pennsylvanian section, but this may reflect less intensive search in collecting. From the northern midcontinent district, 11 species, assigned to 8 genera, have been described from Virgil beds, and 3 new species from Texas are shortly to be added.

In addition to the Pennsylvanian crinoids, record should be made of 14 described Permian species, represented by less than three dozen specimens, 11 of these species being from a single horizon and locality in the Lower Permian of western Texas.

Only 2 genera and 2 species of crinoids have been reported from Permian rocks north of Texas; they come from the Luta limestone of southern Kansas. Five new species of Permian crinoids are described in the Texas paper already mentioned.

Upper Carboniferous crinoids from continents other than North America are as yet recorded only from the Soviet Union in eastern Europe, and in China. The fauna from the vicinity of Moscow, Russia, comes from the Mjatschkowa beds, which contain guide fossils indicating a lower Upper Carboniferous (Des Moines) age. Originally made known by the work of Trautschold (1867, 1879), generic revisions have increased the number of recognized genera of crinoids found here to 12, and there are 13 described species. The species of Upper Carboniferous crinoids from China are from the Taiyuan series, in the northern part of that country, and the age of the beds is thought to be older than Virgil; 12 species and varieties, assigned to 4 genera, are described (Tien, 1926), based entirely on fragmentary remains that were used in part for reconstruction of dorsal cups.

Much the richest and most varied crinoid fauna of Permian age found anywhere in the world is that of the island of Timor, in the East Indies. Made known by the splendid series of publications by Wanner (1916, 1924, 1937), this crinoid assemblage numbers more than 100 genera and 320 species. There are numerous interesting points of resemblance between some of the Timor crinoids and certain American Carboniferous and Permian crinoids, but many of the Timor forms are very unlike any known fossils found on this continent. Permian crinoids have been found in Sicily, associated with ammonites and other fossils

described by Gemmelaro and others, but the crinoids, studied by Yakovlev (1934), are not common, numbering only 6 genera and 7 species. Yakovlev (1926–1933) has described some 15 genera and 20 species of Lower Permian crinoids from the Ural Mountain region of eastern Russia and Novaya Zemlya, several genera corresponding to those reported from Timor, but with a few exceptions, there is little similarity to forms known in North America. Crinoids are found also in Permian rocks of Australia in the so-called Upper Marine series; they include 2 genera and 8 species, described by Etheridge, Jr. (1892). Finally, mention may be made of the occurrence of crinoids in the Permian rocks of the Salt Range, northern India, where 8 species, referred to 4 genera, have been found (Waagen, 1887).

Stratigraphic Relations of Known Crinoids from the Upper Pennsylvanian and Lower Permian Rocks of the Northern Midcontinent Region

With one exception, all of the crinoids described in this paper were collected from beds belonging to the Virgil series, which is the uppermost main division of the Pennsylvanian subsystem and the Carboniferous system, or occurring in the Lower Permian strata that have been called the Big Blue series in Kansas and Nebraska. In order to show the stratigraphic classification, general lithologic nature, approximate thickness, and relative position in the upper Pennsylvanian and Lower Permian column in Nebraska, Kansas, and northern Oklahoma, a diagrammatic section of these beds is given in Fig. 1. The strata are remarkably uniform in character and are extremely persistent, so that a measured section along the Kansas-Oklahoma boundary corresponds in many details to sections in central Kansas, along the Kansas-Nebraska line, and near the northern limit of the Permian exposures in Nebraska. Even the thickness of many of the units is about the same, and there are very numerous beds that are only a few inches or a few feet thick that can be traced for hundreds of miles along the outcrop. Distinctive lithologic and faunal characters that mark many of these beds, checked by very detailed surface mapping and by determination of like sequences

of beds in many exposures, make unusually precise and definite identification of formations and subdivisions of formations at almost any outcrop. This stratigraphic framework, which leaves little to be desired from the standpoint of information as to

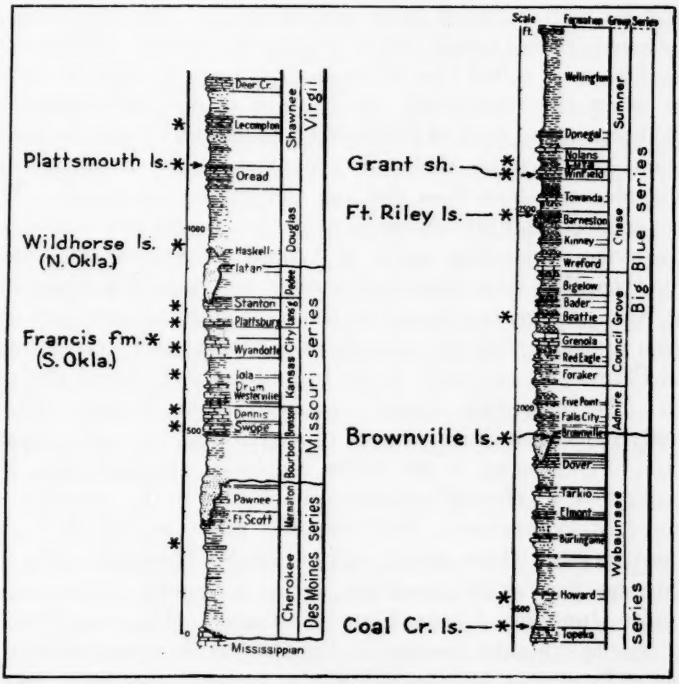


FIG. 1. Columnar sections showing main stratigraphic divisions of the Virgil series, uppermost Carboniferous, and Big Blue series, Lower Permian, in southern Kansas. Horizons from which species of crinoids have been described, including those published in this paper, are indicated by an asterisk (*).

vertical position of any discovered fossils, is the result of several years of painstaking field studies, chiefly by stratigraphers of the Kansas and Nebraska state geological surveys.

The chief crinoid-bearing stratigraphic unit among Virgil and Big Blue deposits, as indicated by new species that are described

here, is the Brownville limestone. This formation occurs at the very top of the Wabaunsee group and contains the youngest Pennsylvanian sediments in the northern midcontinent area (Moore, 1937, p. 244). It was named from a locality in southeastern Nebraska and is traced across Kansas and northern Oklahoma without question as to identification. The limestone is continuous except locally where pre-Big Blue erosion removed it. The limestone called Grayhorse in Oklahoma is some 15 to 30 feet below the Brownville, but the line of outcrop mapped as Grayhorse across most of Oklahoma is apparently based on observations of exposures that are equivalent to the Brownville in most places, rather than the less continuous Grayhorse. The obscure but important disconformity that occurs just above the Brownville, separating rocks of typical Pennsylvanian aspect from those that correspond in characters to typical Big Blue beds, has been pointed out by me as the most suitable boundary between divisions that are classed, respectively, as Pennsylvanian and Permian in this part of the United States (Moore, 1937, p. 13). The Brownville crinoid faunule has been obtained almost wholly from a single small part of its outcrop, located in Osage County, Oklahoma, a few miles southwest of Pawhuska, the county seat. Crinoidal remains are observed in the formation at almost every exposure, but the only place outside of Osage County, Okla., where dorsal cups of crinoids have been collected from the Brownville limestone, so far as known to me, is at Admire Junction, Lyons County, Kansas. The comparative richness in crinoidal remains of the Brownville limestone southwest of Pawhuska, Oklahoma is almost certainly not due to actual greater abundance of these fossils here than in various other places in this formation, although some parts of it are undoubtedly less fossiliferous than in the northern Oklahoma outcrops. The success in collection of fossil crinoids in this region is due in large part to the existence and condition of exposures of the Brownville limestone along railroad cuts near Strohm, Okla., but more to the interest and extremely painstaking search of these outcrops by the track supervisor on this division of the Santa Fe railroad, Mr. Paul McGuire.

The most common crinoids of the Brownville limestone are specimens of a rather large species of *Delocrinus*. Partly because this genus occurs also more abundantly than other genera in other upper Pennsylvanian and Lower Permian beds, and because differentiation of forms having stratigraphic usefulness calls for close comparative study of all available material, this division of the Brownville crinoid fauna is excluded from this paper; time has not permitted adequate study.

Species of crinoids, other than those from the Brownville, are introduced mainly because they supplement work on the Brownville forms. Those from eastern Osage County, Oklahoma, from a lower Virgil horizon, occur about 35 feet below the Wildhorse limestone, a discontinuous member of the Nelagoney formation that appears to belong very close to the horizon of the Haskell limestone, if it is not precisely equivalent to this marine unit. The lower Virgil deposits are mainly continental in origin, and in the eastern Osage County area they consist largely of cross-bedded sandstone and reddish shale. Two representatives of *Utharocrinus* are described from limestone formations of the Shawnee group, but numerous other crinoids from this part of the section await description.

Previous Work

Studies of crinoid species occurring in the Virgil and Big Blue strata of the northern midcontinent region have been published by nine previous workers. H. B. Geinitz (1866) is the author of the first described species, called *Cyathocrinus inflexus*, now referred to *Delocrinus* Miller and Gurley, which was collected from middle Wabaunsee beds, just above the horizon of the Tarkio limestone, at Nebraska City, Neb. The type specimen, which is preserved at Harvard University, is a distorted cup, but it shows fairly well certain characters of shape that distinguish it from described middle and lower Pennsylvanian species belonging to this genus. F. B. Meek (1872) described an incomplete crown of a *Delocrinus* from the neighborhood of Omaha, Neb., naming it *Scaphiocrinus? hemisphaericus* (Shumard), and he refigured Geinitz's illustration of *D. inflexus*, referring it to Shu-

mard's species. The horizon from which Meek's specimen was obtained is doubtful; it may have been found in Wabaunsee beds, which are exposed along the Missouri River below Omaha, but more probably it came from the Shawnee group. The specimen does not appear to belong under *D. inflexus*, as considered by Miller and Gurley and Weller, but is surely not an example of Shumard's species.

In 1867, C. A. White and O. H. St. John described a moderately large subglobose crinoid cup with thick plates bearing decoration of ridges; the type specimen, which came from "Upper Coal Measures" in southwestern Iowa, was named *Hydreionocrinus? verrucosus*. The exact horizon to which this species belongs is not known, but it is very probably within the Virgil series. The type, now in my possession on loan from the State University of Iowa, indicates that the species may be assigned to a new genus that is defined in a paper now in press (Moore and Plummer, 1939).

Three species of Virgil crinoids, called *Cyathocrinus stillativus*, *Lecythiocrinus olliculaeformis*, and *Erisocrinus* (*Ceriocrinus*) *planus*, were described by White in 1880 (also 1882). They are reported to have been collected "30 miles west of Humboldt, Kansas," which signifies a horizon well above the base of the Virgil series, and from examination of the state geological map (Moore and Landes, 1937) is determined probably to be the Oread limestone, the lowermost formation of the Shawnee group. The first named species is referred to a new genus (Moore and Plummer, 1939)[2], the second is valid, and the third is now assigned to *Paradelocrinus* Moore and Plummer. Wachsmuth and Springer (1886, p. 255) erroneously sought to transfer *E. planus* to a specimen which White called *Poteriocrinus hemisphericus* Shumard, figuring it for the sake of comparison with *E. planus*, and the latter Wachsmuth and Springer renamed *E. whitei;* when they discovered that the latter name was a homonym of *E. whitei* Meek and Worthen (1865), they inserted a note in separates of

[2] Publication by H. L. Strimple (1939a, in bibliography at end of this paper) of the name *Whiteocrinus* for this genus has priority over the name to have been introduced in the Texas report.

their paper that were privately distributed, changing the name of their *E. whitei* to *E. cognatus*. It is clear that neither of Wachsmuth and Springer's designations for this fossil have any standing.

The next contributions to knowledge of Virgil crinoids consist of publications by J. W. Beede (1899, 1900, 1902) describing four species from the Howard limestone, in the lower part of the Wabaunsee group, near Topeka, Kans. These species, called *Ceriocrinus harshbargeri*, *C. monticulatus*, *Erisocrinus megalobrachius*, and *Scaphiocrinus? washburni*, are represented by types that show the arms more or less completely, as well as the dorsal cups. The first named species is now referred to *Delocrinus*, the second to *Paradelocrinus*, the third to *Ethelocrinus* Kirk, and the fourth to a new genus (Moore and Plummer, 1939).

Stuart Weller (1898) described an interesting, nearly complete crown of a crinoid from the Lecompton limestone, in the middle part of the Shawnee group, from Greenwood County, Kansas. This species, named *Hydreionocrinus kansasensis* by him, is assigned by me to *Neozeacrinus* Wanner.

The only described crinoids from Permian rocks in the northern midcontinent country are two species, *Delocrinus conicus* and *Erisocrinus lutana*, described by Margaret Fuller Boos (1929). These species occur in the Luta limestone, at the base of the Sumner group, *D. conicus* being distributed from southern Kay County, Oklahoma, northward to central Kansas, and *E. lutana* from central to northern Cowley County, Kansas, near Winfield. As noted elsewhere in this paper, *E. lutana* is certainly not an *Erisocrinus*, and it is tentatively designated as *Pachylocrinus lutanus* (Boos).

Acknowledgments

The opportunity to study and describe the excellent collection of fossil crinoids from the Brownville limestone of central western Osage County, Oklahoma, is due to the kindness of my friend, Mr. Paul McGuire, supervisor of a division of the Atchison, Topeka and Santa Fe railroad track lying west of Pawhuska, Okla. Mr. McGuire's address is Fairfax, Okla., but his residence is at the loading station of Strohm, on the Santa Fe some 10 miles

northeast of Fairfax. Partly through interest communicated to him by Mr. E. L. Banion, district supervisor for the Santa Fe, formerly living in Independence, Kans., Mr. McGuire began a few years ago to devote as much as possible of his spare time to collecting fossils, rocks, and mineral specimens and studying them. Discovery of the fine specimen of a flexible crinoid crown, here described as *Trautscholdicrinus mcguirei*, n. sp., led to intensive search for other crinoid specimens, and during a period of some two years, various lots of crinoids from the Brownville and other formations in Oklahoma and southern Kansas have been sent by him to me. The specimens are the property of Mr. McGuire, but he has given assurance that type material will be deposited under his name in a suitable geological museum for safe keeping. Plastotypes are placed in the paleontological museum of the University of Kansas. I express to Mr. McGuire my appreciation of his kindness in entrusting very numerous specimens to me for study, and of his hospitality on the occasion of various visits to his collecting localities. Mr. Banion accompanied us on some trips, and cordial thanks are also due him for many specimens given by him to the University.

Acknowledgments and sincere thanks are expressed for fossils described in this paper that were collected by Mr. Arthur L. Bowsher, of the University of Tulsa, and by Mr. A. R. Loeblich, formerly of the University of Oklahoma, now at the University of Chicago. Mr. H. Allison Tourtelot, of the University of Nebraska, collected the specimen on which *Nebraskacrinus* is based, and Dr. George E. Condra and Mr. W. R. Johnson, of the Nebraska Geological Survey, loaned this and other Nebraska material for study. Two of the Kansas crinoids described in this paper were collected by Mr. Arthur Bridwell, of Baldwin, Kans., and I wish to indicate appreciation of aid given by him in furnishing these and numerous other crinoids.

The loan of type specimens by various individuals and institutions, preparation of plastotypes, and contribution or loan of many specimens of undescribed crinoids, as noted in a previous paper (Moore and Plummer, 1938, p. 215), have been of utmost value and I am very grateful for this help. Omitting special

notations, because of limited space, I may nevertheless record the names of several to whom I am specially indebted: Robert Allison, R. S. Bassler, Joseph Borden, C. C. Branson, H. A. Buehler, Edward Butts, J. E. Carman, A. C. Carpenter, Carey Croneis, C. E. Decker, Carl O. Dunbar, W. H. Easton, John D. Ewers, L. E. Fitts, Jr., C. L. Foster, Don B. Gould, Allen Graffham, Mrs. George Harris, H. R. Hancock, J. M. Jewett, J. Harlan Johnson, W. D. Keller, J. B. Kleihege, Lowell R. Laudon, Mrs. W. R. Marrs, Arthur K. Miller, Carl A. Moore, Norman D. Newell, W. T. O'Gara, F. B. Plummer, H. C. Price, Percy E. Raymond, W. F. Read, Gayle Scott, John Skinner, Bob Stevens, A. H. Sutton, Ben Taylor, Churchill Thomas, F. O. Thompson, I. P. Tolmachoff, C. W. Tomlinson, John Waugh, J. Marvin Weller, and James Wright.

Thanks are expressed to Mr. Oren C. Bingham, director of the photographic laboratory of the University of Kansas, for careful work in photographing specimens of crinoids illustrated in this paper.

A grant by the Graduate Research Committee of the University of Kansas aided in completing this study.

NOTES ON TECHNIQUE IN THE DESCRIPTION AND ILLUSTRATION OF CRINOIDS

Symbols for designation of crinoid plates.—The letter symbols that have been devised by Bather, and Wachsmuth and Springer for the designation of crinoid parts have become almost universally used by paleontologists in descriptions of crinoids, for they have the advantages of simplicity and brevity. For the benefit of students who may not be familiar with the symbols, those most commonly used are explained here. Proceeding upward from the base of the cup, the designation of plates is as follows: infrabasal (IB), infrabasals (IBB); basal (B), basals (BB); radial (R), radials (RR); radianal (RA); anal plate (x); right tube plate of anal series (rt); left tube plate (lt); primibrach or primibrachs (IBr); secundibrach or secundibrachs (IIBr); tertibrach or tertibrachs (IIIBr); a particular brachial may be indicated by a subscript number (for example, IBr_3) that marks

its position, counting upward from the lowermost segment of the series designated. An axillary primibrach may be designated IAx, and a similar plate of the secundibrach series by IIAx. Each plate of any given circlet may be indicated by symbols referring to position: posterior (p), right posterior (rp), left posterior (lp), anterior (a), right anterior (ra), and left anterior (la). Thus pB indicates the posterior basal plate, and rpR, the right posterior radial plate.

Measurements of crinoids.—The main purpose of most crinoid measurements is to facilitate comparisons between somewhat closely related forms. Also, it is important in some cases to record by measurements features that cannot be shown clearly in illustrations, as for example, the height of the basal concavity in a cup having a depressed base. Older descriptions of fossil crinoids, and unfortunately, some modern ones, are frequently lacking in information concerning features that were not considered of any importance at the time of writing the description but that later may come to be regarded as very significant. Quantitative data usefully supplement qualitative statements, and there is generally danger of too few, rather than too many observations that may be recorded in millimeters. It is needful that measurements be made in a uniform manner and that the manner of making them should be understood by one who reads the descriptions. It is desirable, therefore, to introduce brief explanation of some features involved in crinoid measurements according to my methods.

Generally speaking, the most important features of reference in measurement of crinoid cups are (a) the plane tangent to the base of the cup, known as the basal plane, and (b) an axis normal to the basal plane intersecting it in or directly below the center of the stem impression. The position and inclination of any of the plates of the cup may be indicated adequately by reference to these two geometrical elements.

The height of the dorsal cup, which has been interpreted varyingly by different authors, is here uniformly considered to be the vertical distance from the basal plane of the cup to the level of the transverse ridge of the aR plate. This represents as

precisely as possible the actual height of the cup as seen in a specimen with the arms in place. For several reasons, it is considered undesirable to include in this measurement parts of the cup, such as upward projecting parts of the radial facets and plates of the anal series, that lie above the transverse ridge. The aR is chosen because the posterior part of the cup is found to be irregular in many cases, the lpR being commonly somewhat lower than the rpR.

The greatest width of the cup is a straight line measurement between the most widely separated points on the cup lying approximately parallel to the basal plane. Possibly another type of width measurement, as through the anterior radius and posterior interradius, or in some other specified direction across the cup, might be useful, but this is not the method that I have employed. Obviously, computation of the ratio of height to width of a dorsal cup depends on the manner of making these two measurements.

Height of the basal concavity in crinoid cups having a depressed base is considered to be the vertical distance from the basal plane of the cup to the center of the stem impression. In some cases where the posterior side of the basal area remains well above the basal plane, as in various hydreionocrinids, the basal concavity lacks the form of an enclosed hollow, but it is treated as a basal concavity nonetheless. Also, it is desirable to note that the inclusion of the concave stem impression in making measurement of the basal concavity may give appreciably different results as compared with measurement excluding it.

Straight line distances across plates, longitudinally and transversely, are generally determinable from illustrations of crinoid cups. In recording measurements of the length and width of individual plates, it has seemed preferable to take account of curvature of the plate surface, and such measurements are made along the surface. Because slight variations in size and shape are commonly found in plates belonging to the anterior and posterior sides of a cup, the raB and aR are selected for measurement rather than random plates belonging to these circlets.

Cross sections of crinoid cups.—Good photographs of a crinoid

cup, giving views of the base, top, and one or more sides, afford adequate information concerning many crinoid species, provided care is taken to see that important structural features, such as position of suture lines, are clearly shown. Because of difficulty in securing satisfactory photographs, many published illustrations of crinoids consist of wash drawings, and if these are made very carefully and skillfully they may be superior to other figures.

A type of drawing that is believed to have much value in the study of many crinoid cups is a cross-section along one or two uniform directions that are chosen so as best to indicate structural features of the cup. Such a drawing is comparable to the very informative and useful representations of the shells of ammonoids, as prepared by H. Schmidt (1925) and others (see Plummer and Scott, 1937, p. 12), showing the form in cross section. A section commonly serves to give information that can be shown in no way by photographs or by drawings of the exterior of the cup. This refers particularly to delineation of such features as the exact curvature of the median profile of various plates, the height of various points above the basal plane, the lateral distance from the center of the stem impression to various suture junctions between plates, and the height and shape of the basal concavity, when this is present. The true profile of a cup in side view is ordinarily not shown, unless an exceptionally long focus lens is used in photographing it, or unless particular attention to the matter of parallax is devoted to construction of drawings. On the other hand, an accurate representation of the contour of a cup along a selected line across it can be made without actually sawing through the specimen along this line. After dusting the surface of the specimen with talcum powder so that plasticene or similar molding clay will not adhere to the surface, such clay may be pressed firmly against part of the cup and may be sliced with a fine needle so that the edge of the clay comes exactly along the selected line across the cup. The position of sutures along the profile may be marked, and generally it is possible and desirable to indicate on the clay the position of the basal plane of the cup, for this may touch the line of the profile at only a single point, or exceptionally, may lie entirely below it. A little care and

practice will enable one to remove the impression from the crinoid without slightest distortion of the profile thus recorded, but it is desirable to perform all of the operations just described while working with a binocular microscope under low power. Naturally, impressions that involve overhangs of the plasticene cannot be removed from the crinoid satisfactorily, and it is sometimes necessary to construct drawings from two or more segments. Impressions of the inside, as well as the outside, of the cup are made in some cases, but often this is not possible and the drawing of this part of the cross section is guided by information on the thickness of the radial plates and by knowledge of the interior of related cups. This part of the drawing is much less important than that which shows the form of the exterior and is added partly for the sake of appearance; similarly, drawing of the portions of the cup beyond the plane of the selected cross section is not needful, but it contributes to understanding of features shown in the cross section.

Comparative study of crinoid cups in cross sections calls for construction of one drawing through the antero-posterior axis, because this shows the nature of the posterior interradius and also because the section passes through the center of a radial plate (aR). Another section passing through the midportion of the lpR and between the aR and raR, is useful mainly because it passes through the midportion of a normal basal (raB) and gives a profile at the position of an interradial suture. Drawings of this type were first used by Moore and Plummer (1938, pp. 265, 278, 282, 290, 296), and it is believed that figures of this type are very helpful, if not absolutely required, in order to show certain features definitely and clearly. Several cross sections of crinoid cups, prepared in the manner described, are published in this paper.

Studies of separate plates.—Although a certain amount of variation in the shape and size of plates belonging to the dorsal cups of different species of crinoids may be expected, close observation shows that in a majority of cases distinguishing features can be found that serve not only as means for recognition of plates belonging to different genera, but also those of different species.

It is not possible, of course, thus to allocate every single dissociated plate that may be found, but comparative study of the form of plates in complete dorsal cups and of many hundreds of dissociated plates collected from the Brownville limestone and other formations indicates the value of somewhat exact determination of characters of these individual components of the crinoids.

One of the chief requisites for satisfactory comparative study of crinoid plates is a standard method for orienting them, so that the nature of angles between intersecting surfaces and the nature of variously curved surfaces may be viewed uniformly. The importance of this is obvious, and more or less rigorous methods of orientation are applied to almost all groups of fossils in scientific description and illustration. Definition of significant measurements and a method for orientation of isolated crinoid plates, deemed most satisfactory, are given in one of my previous papers (Moore, 1939). Diagnostic features are most commonly shown by radial plates and second to these are primibrach segments, infrabasal circlets, and basal plates.

In the study of a radial plate, first attention is given to the median profile and cross section. In some cases observations may be made satisfactorily directly from the plate mounted on a bit of plasticene under the microscope, the plate being oriented so that the midpoint of the outer margin of the facet is focally even with the proximal tip of the plate and directly above it (Moore, 1939, pp. 215, 218). Generally it is necessary, or at least advisable, to make an impression in plasticene of the plate in median profile, powdering the plate so that it does not adhere to the plasticene and using a needle under the microscope. It is possible to prepare this impression in exactly the position desired, and care in removing the plasticene from the plate gives perfect representation of the contour in the selected plane. This may be reproduced photographically, by drawing with micrometer eyepiece, or with camera lucida. The planes of the outer and inner ligament areas with respect to the long axis of the plate, curvature of the outer surface along the midline and other features can thus be determined. Turning the plate exactly 90

degrees in four different directions gives oriented views of the exterior, top, interior, and bottom sides of the plate. The angle of the facet of a radial plate may be measured from a drawing of a median profile.

The curved outer surface of plates may be measured so as to give mathematical expression to the amount and location of convexities. In side view of a radial plate, for example, the curvature of the median profile may be indicated approximately by locating the point of maximum departure from the vertical line, and the amount of this departure, expressed as ratio of the distance above the proximal tip and below the margin of the facet may be employed as a convexity index. Plotting one of these ratios as an ordinate and the other as an abscissa, a point can be located on a graph which gives expression to the convexity form of the plate under study. Points thus plotted for many plates show the nature and extent of their variation in convexity. If desired, similar methods of analysis and graphic representation could be applied to other characters of the plates, for example, the ratios of the length of the outer ligament area to that of the transverse ridge, and that of the maximum bulge of the outer surface of the plate in top view through the transverse ridge. In some cases, this study of plate convexity appears to have little or no value, however.

SYSTEMATIC DESCRIPTIONS

Order FLEXIBILIA Zittel

Suborder SAGENOCRINOIDEA Wachsmuth and Springer

Family LECANOCRINIDAE Springer, 1920

Genus CIBOLOCRINUS Weller, 1909; emend. Moore and Plummer, 1938

Cibolocrinus WELLER, *1909*, Jour. Geology, vol. 17, p. 630. ——— WANNER, *1916*, Paläontologie von Timor, Lief. 6, p. 206. ——— MOORE AND PLUMMER, *1938*, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (1937), p. 225.

The dorsal cup belonging to this genus is bowl-shaped or somewhat turbinate, without a basal concavity except for the sharply defined hollow of the stem impression, which is generally vertical-sided and lacking in crenellae. There are three IBB,

two of which are large and one small; the small IB is located in the right posterior radius in most cases, but in the genotype species it is more commonly in the anterior radius. The five BB are moderately large, nearly equal and approximately as long as wide; the pB is squarely truncated distally for contact with the anal x plate. The RR are characterized by the shortness of their facets, which are divided by a well marked transverse ridge into a very short outer ligament area with a wide, deep ligament pit, and an inner ligament area with distinctly depressed lateral borders. The very short incurving arms are formed of Br that are much wider than long; an isotomous division occurs on the IBr_2, and this very low axillary plate is followed by 6 or more IIBr that diminish rapidly in size upward. The stem is round.

Remarks—This genus has been assigned by other authors to the Poteriocrinidae Roemer (= Poteriocrinitidae Bassler), but it has been shown in a previous paper (Moore and Plummer, 1938, p. 225) that two distinct kinds of crinoid cups were included by Weller in *Cibolocrinus*, the one represented by the genotype species having facets like those of lecanocrinid flexible crinoids and the other having facets like those of common poteriocrinids. The definition of the genus was emended to exclude the latter forms, and largely on the basis of facet characters and the structure of the IBB circlet, *Cibolocrinus* was placed among the Flexibilia. Recent discovery of a complete crown belonging to this genus has established firmly its transfer to a position in the Lecanocrinidae, for the arms are those of a typical representative of this family and not at all like the arms of an inadunate crinoid. The specimen with arms was collected from the basal part of the Marble Falls limestone, Morrow series, lower Pennsylvanian, near San Saba, Tex., by Frederick B. Plummer and Gordon Fisher, of the University of Texas; it represents a new species that is described in another paper (Moore and Plummer, 1939).

Occurrence.—Upper Carboniferous, Morrow to Virgil series, and Lower Permian, Texas, Oklahoma and Kansas.

Genotype.—*Cibolocrinus typus* Weller, from the Cibolo (Wolfcamp) limestone, Lower Permian, Presidio County, Texas.

CIBOLOCRINUS BANIONI Moore

Plate V, figures 3–8; plate VII, figure 7; text figures 2, 3

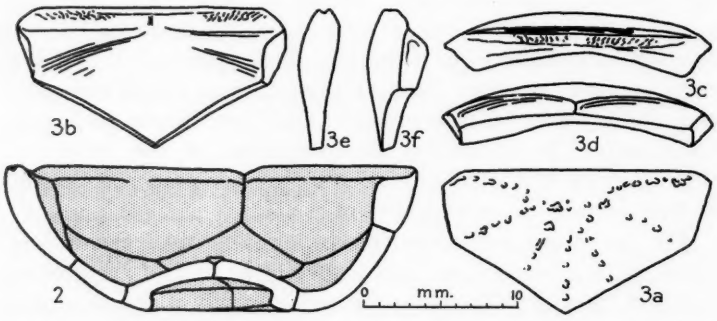
Description of this interesting representative of the genus *Cibolocrinus* is based on fragmentary remains of dorsal cups of different size, and a few brachials. It has been possible from material at hand to make partial restoration of two cups. One of these, which is designated as holotype, consists of an infrabasal circlet with two attached basals to which have been joined two isolated basals and three radials of proper size. Another partially reconstructed cup consists of the two posterior RR and intervening anal plate, to which have been joined an R and B of corresponding size; since these plates were found closely associated and match perfectly, it is probable that they belong to a single individual. The distinctive ornamentation of the surface of these plates permits little question as to their proper association as representing the same species of crinoid.

The dorsal cup has a moderately low, slightly truncate bowl shape, with a height one-third to two-fifths that of the greatest width of the cup. The sides are rather evenly rounded, and an outward flare continues to the summit of the RR.

The IBB circlet forms a regular pentagon that carries a somewhat deeply excavated stem impression, almost equal in diameter to the greatest width of the disk. The border of the stem area is a vertical wall (Fig. 2), nearly a millimeter in height. There are no marks of crenellae on the impression. The distal parts of the IBB are confluent with the proximal surfaces of the BB. Somewhat obscurely shown on the exterior, but clearly visible on the interior, are the sutures between the three IBB; the small IB constitutes one-fifth of the circlet and the other two plates each comprise two-fifths of the circlet. The interior surface of the specimen selected as holotype rises in the form of a low cone, but in another example, the interior of the plate forms a nearly horizontal surface. Both specimens show a low, triangular rim surrounding the lumen, the points of the triangle being directed toward the midportions of the three plates. It is clear from the mode of attachment of the regular basals that the location of the

small IB is not in the anterior ray; so far as can be determined, its position appears to be in the right posterior ray.

The BB are of essentially uniform size and are pentagonal in outline, except the pB, which is somewhat larger than the others and has an hexagonal outline. The length of these plates is equal to the width. A gentle transverse curvature is almost exactly matched by the longitudinal curvature. The plates are of moderate thickness (about 1.5 mm.) and the suture faces are



FIGS. 2 AND 3. Drawings of the dorsal cup of *Cibolocrinus banioni*, n. sp., in cross section, and of a radial plate. *2*, Median cross section of the holotype specimen, showing the vertical-sided stem impression; orientation of the section through the middle of the lpR and raB, the part of the cup beyond the plane of the section shaded. *3a*, Exterior view of a radial plate (laR, raR or aR) of a large specimen, used in reconstruction of an incomplete dorsal cup that is classed as a paratype; *3b*, interior view; *3c*, top view; *3d*, bottom view; *3e*, side view; *3f*, median cross section.

very slightly excavated for reception of ligament fibers, the narrow margins of the sutures bearing fine denticles.

The RR are pentagonal in outline, and the width is almost twice the length, except in the case of the two posterior RR, which are reduced in width and asymmetrical in outline because of introduction of anal x. The longitudinal profile of these plates is nearly straight (Fig. 3f), but there is a gentle transverse curvature which, however, is not enough to change the outline of the

cup from a somewhat distinctly pentagonal outline to one that is circular. The articular facet is very short, for it is produced by only a moderate thickening at the summit of the plate. A straight transverse ridge intersects the margin of the facet at a distance of about 2 mm. from the summit of the interradial sutures, and there is a very short, somewhat deeply excavated outer ligament area. The inner part of the facet slopes steeply inward, and is without special markings except for the somewhat shelflike projection near the edges of the plates (Fig. 3). This shelflike area lies somewhat farther below the summit of the RR than in the case of *C. typus*.

The single anal plate rests squarely on the truncated distal extremity of the pB, and about half of its height extends above the summit of the RR. Its longitudinal profile is nearly vertical, but transversely it is concave toward the posterior side of the cup. This plate, in the large paratype specimen, shows sutures for union with four plates in the part that lies above the summit of the RR.

Three isolated brachials that have been collected show that the first primibrach is a short quadrangular segment with a length only about one-fifth of the width. One of the observed brachials is an axillary, but the length of this plate in the middle is hardly greater than that at the lateral extremities (Pl. V, figs. 7 a–c). The shape and articular markings of these segments are almost identical with those of the specimen of *Cibolocrinus* with arms that was collected from the Marble Falls limestone in Texas, described in another paper (Moore and Plummer, 1939). The brachials are typical of those seen in lecanocrinid representatives of the *Flexibilia*.

The surface of the plates is ornamented by a fine granulation, and by coarser, somewhat irregular placed pimple-like projections. The latter protuberances seem to be most prominent on the central parts of the BB, and there is suggestion of a definite arrangement on some of the RR, in which the pimples form rows running from the angles of the plates and the middle of the two lower edges to the upper midportion of the RR (Fig. 3a).

Measurements of the type specimens are given in the following tabulation:

Measurements of Cibolocrinus banioni, n. sp., in millimeters

	HOLOTYPE	PARATYPE
Height of dorsal cup	10.4	11.2
Greatest width of cup	26.0	35.0
Ratio of height to width	.40	.32
Width of stem impression	8.0	—
Height of concavity of stem impression	2.4	—
Length of basal plate	11.2	11.4
Width of basal plate	11.6	12.1
Length of radial plate	16.5	19.2
Width of radial plate	8.1	10.6

Remarks.—This species shows clearly the distinctive features of the articular facets, the general form of the cup, and the excavated nature of the stem impression that are seen in the genotype species, *C. typus* Weller. The new species from the Brownville limestone attains the width that is seen in the Lower Permian species from western Texas, but it is proportionately somewhat lower, and is distinguished by the peculiarities of its surface ornamentation. *C. tumidus* Moore and Plummer from the Brentwood limestone, Morrow series, of northwestern Arkansas and northeastern Oklahoma, has a steeper-sided cup, much more bulbous plates, and a different surface ornamentation.

This species is named for E. L. Banion, Marceline, Mo., in recognition of important assistance given in collection of crinoids from southern Kansas and northern Oklahoma while he was a resident at Independence, Kans. Mr. Banion collected part of the material on which description of this species is based.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); Loc. 4578, cut on Santa Fe railroad, 7 miles west of Strohm, Osage County, Okla., collected by E. L. Banion, Paul McGuire and R. C. Moore.

Types.—Holotype, partially reconstructed specimen, Kansas Univ. 45784, paratype no. 45785, brachials, nos. 45786a–c; infrabasal circlet, no. 45787; all from the locality 7 miles west of Strohm.

Family ICHTHYOCRINIDAE Wachsmuth and Springer, 1897
Genus TRAUTSCHOLDICRINUS Moore and Plummer, 1939

Trautscholdicrinus MOORE AND PLUMMER, *1939*, Mss. Univ. Texas Bull., (in press).

Synerocrinus Jaekel, BATHER, *1899*, British Association, Report for 1898, p. 923; *1900*, Treatise on Zoology (Lankester), pt. 3, p. 190. ——— SPRINGER, *1902*, Am. Geologist, vol. 30, p. 95; *1906*, Jour. Geology, vol. 14, p. 519; *1913*, in Zittel-Eastman, Text-book of Paleontology, p. 205; *1920* Crinoidea Flexibilia, Smithsonian Institution, Pub. 2501, p. 334. ——— ZITTEL, *1910*, Grundzüge der Paläontologie, p. 166.

This genus, described in manuscript prepared more than a year ago, is defined to include crinoids that currently have been assigned by authors to *Synerocrinus* Jaekel. It is shown that although Jaekel based his genus on Trautschold's species, *Forbesiocrinus incurvus*, as genotype, he misinterpreted that species by accepting as a valid representative of it a crinoid that differs significantly from Trautschold's actual type, an error that is traceable to Trautschold's publication in 1879 of figures of a flexible crinoid with heterotomous arms, identified by him as *F. incurvus*. Trautschold's original figures (1867) and his descriptions, published both at this time and twelve years later, definitely indicate a crinoid with isotomous arms. Crinoids that correspond in every structural feature to the original types of *F. incurvus*, but not to the form with heterotomous arms, which Jaekel intended to designate as *Synerocrinus*, have been found in Texas. These are assigned to *Synerocrinus* because under the Rules of Zoological Nomenclature it is evident that the types of the designated genotype species, rather than Jaekel's ideas of what constituted his new genus, must govern use of this name. This deprives the crinoid with heterotomous arms of a name, and *Trautscholdicrinus* is introduced to designate it. These matters are discussed in some detail in the Texas paper.

The crown of *Trautscholdicrinus* is rounded in outline, the sides curving evenly upward from the border of the stem impression to a maximum width at about the height of IIAx. All of the IBB circlet and the proximal parts of the BB are included in the area of the stem impression, but the RR and succeeding arm plates are outside of this. There are two isotomous branch-

ings in each ray, but above the second bifurcation the arms are heterotomous, with simple ramules on the inside of the dichotoms. The rays are joined above the RR by interbrachials that number four to twelve in each inter-ray, and additional interbrachials may be present between the bifurcations of the ray. An RA is absent, but anal x is located on the truncated tip of the pB. The relatively large round stem expands proximally and is composed of very thin segments.

Genotype.—Trautscholdicrinus jaekeli Moore and Plummer, from beds near Moscow, Russia, classed as belonging to the upper part of the Lower Carboniferous. The specimen figured by Springer (1920, pl. 42, figs. 4a and 4b) from the collection in the U. S. National Museum, is designated as holotype, called by Springer *Synerocrinus incurvus* (Trautschold).

Occurrence.—Upper part of Lower Carboniferous, Russia and Scotland; Morrow series, Pennsylvanian (Upper Carboniferous), southern Oklahoma; top of Virgil series, uppermost Pennsylvanian, northern Oklahoma.

TRAUTSCHOLDICRINUS MCGUIREI Moore, n. sp.

Plate V, figures 2a–c

A very well preserved, nearly complete crown furnishes basis for description of this new species. The specimen is somewhat distorted, so that measurements of the height and greatest width of the cup are only approximate, but the structure of all parts of the crown is clearly evident, except the basal part of the cup that is covered by attached proximal segments of the stem.

The IBB and all but the distal extremities of the BB lie within the area of the stem impression. The pB, identifiable by its truncated extremity, extends much farther beyond the stem area than the other BB. The RR are almost entirely outside of the stem area and are followed by two IBr that are somewhat larger than the RR. There are three IIBr in each branch and these increase in width upward. Five IIIBr occur typically in each branch, but in one of them there are only four such segments; the two outer branches of each ray above the IIAx plate are little greater in width than the inner branches, and thus a heterotomous character is introduced at the second bifurcation of each ray.

There are typically five, but in some cases only four IVBr, VBr, and VIBr, in the main branches, ramules on the inner side of the brachial columns being undivided. The distal parts of the arms curve strongly inward at the top of the crown.

Each interray is occupied by about 12 interbrachials, the largest of which is the single plate at the proximal margin of the area. The posterior interradius is identified only by the greater projection and truncation distally of the pB. One to three interbrachials are located between the branches of each ray above the $IIBr_1$, but no interbrachials are observed higher in the crown.

The round stem is composed of thin segments of approximately uniform thickness; they expand noticeably, but not strongly, towards the stem impression. The seventeenth columnal below the stem impression contains 42 short, strong crenellae, reaching a little less than one-third of the distance from the margin to the small, strongly pentastellate lumen.

The height and greatest width of the crown, in undistorted condition, are estimated to be about 30 mm. The diameter of the stem impression is 7.2 mm., and that of the seventeenth columnal below the area, 5.4 mm.

Remarks.—In size and general proportions, the type of *T. mcguirei* corresponds closely with that of specimens of *T. jaekeli* figured by Springer (1920). Distinguishing features appear in the much stronger projection of the BB from the border of the stem area in *T. jaekeli*, the more closely spaced branching above the IIBr in that species, and the smaller number of interbrachials observed in the Russian specimens. In *T. mcguirei* a perceptible difference in the width of the arms appears next above the IAx, but is not discernible in the figures of *T. jaekeli*. There are four or five segments between axillary plates in the upper arms of *T. mcguirei*, as compared with only one or two plates in *T. jaekeli*. *T. farishi* (Laudon), from the Bostwick limestone near Ardmore, Okla., is a very much larger and coarser form, in which the arms have an annulated appearance, and in their upper portions there is only one segment between axillary plates that bear ramules.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); Loc. 4604, railroad

cut five miles west of Strohm, Osage County, Okla. Collected by Paul McGuire.

Types.—Holotype, McGuire collection (plastotype Kansas Univ. no. 460415).

Order INADUNATA Wachsmuth and Springer
Suborder FISTULATA Wachsmuth and Springer
Family POTERIOCRINITIDAE Bassler, 1939
Genus NEBRASKACRINUS Moore, n. gen.

Dorsal cup conical, with sides somewhat steeper in the upper part than in the lower, height distinctly greater on the posterior than the anterior side, nearly equal to greatest width of the cup. IBB five, flaring upward, distinctly visible in side view of the cup. BB five, large, subequal, the pB and rpB heptagonal and the others hexagonal, nearly straight longitudinally, length slightly greater than width. RR five, length more than one-half of width, with articular facets equal to greatest width of the plate. Posterior interradius slightly bulging rather than depressed, with three large plates of the anal series in the dorsal cup. Arms strongly rounded externally but with flattened sides, composed of quadrangular, uniserially arranged segments, with all IBr_1 axillary, and excepting the anterior ray, in which the arm structure is not definitely determined, with $IIBr_2$ axillary in one branch of each ray; the branching is heterotomous. Anal sac strong, tapering upward, composed of several columns of plates without intervening respiratory slits in the lower part of the sac; upper part of sac unknown; stem round, pierced by a pentastellate lumen.

Remarks.—Crinoid genera that have dorsal cups resembling that of *Nebraskacrinus* in general shape and structure include *Logocrinus* Goldring from the Devonian, *Poteriocrinites* Miller, *Woodocrinus* De Koninck, *Cercidocrinus* Kirk, *Coeliocrinus* White, *Gilmocrinus* Laudon, *Scytalocrinus* Wachsmuth and Springer, *Springericrinus* Jaekel, *Ulrichicrinus* Springer, *Hydriocrinus* Trautschold, *Moscovicrinus* Jaekel, *Ophiurocrinus* Jaekel, and *Morrowcrinus* Moore and Plummer, all but the first occurring in Carboniferous strata. None of these has the type of arms that are found in the new genus, and on this character mainly they

are to be distinguished. Closest resemblance appears in comparison of *Nebraskacrinus* with *Moscovicrinus*, although the nature of the anal sac in the later genus is not recorded. Branching of the arms in *Moscovicrinus* occurs in each ray on the IBr_2 instead of the IBr_1, and there are minor differences in the mode of branching above the axillary IBr; also the arm segments of *Moscovicrinus* are more rounded and less closely in contact laterally. It seems possible, but is by no means certain, that *Nebraskacrinus* may have been derived from an ancestral form resembling *Moscovicrinus*[3].

Occurrence.—Lower Permian, Nebraska and Kansas.

Genotype.—*Nebraskacrinus tourteloti* Moore, n. sp.

NEBRASKACRINUS TOURTELOTI Moore, n. sp.

Plate V, figures 1a–d; text figure 4

Description of this species is based on four dorsal cups, with one of which the lower part of the arms and anal sac are preserved, and with the others, the lower arm plates. Avoiding repetition of descriptive features given in definition of the genus, it may be noted that the sides of the lower half of the cup in *N. tourteloti* slope upward at an angle of 45° to 50° from the basal plane, except in the upper part of the cup where the slope averages about 75°; the posterior part of the cup, however, is bulged outward so that the surface slopes somewhat inward near the top of the cup (Fig. 4). The profile of the cup and anal sac are nearly symmetrical in anterior and posterior views, but from the right or left side distinct asymmetry in outline appears, due both to the bulge on the posterior side and to a greater elevation, especially of the rpR, of the posterior RR above the stem as compared with the anterior RR.

The IBB circlet forms the lower one-fourth of the cup. The round stem impression, which occupies the proximal parts of the IBB, is marked by about 35 strong crenellae that reach about two-thirds of the way from the margin to the lumen; the opening

[3] A new genus called *Melbacrinus* Strimple (1939), from middle Pennsylvanian beds of northeastern Oklahoma, has a conical cup; it differs from *Nebraskacrinus* in the straight line at the top of the anal plates in the cup and in having some nonaxillary first primibrachs.

of the lumen has a five-rayed floriform outline, and its greatest width is about 0.9 mm. The distal parts of the IBB, lying outside the area of the stem impression, have a length of 6 to 6.5 mm. and an equal width. The BB are large plates with very little longitudinal curvature, slightly longer than wide; the thick-

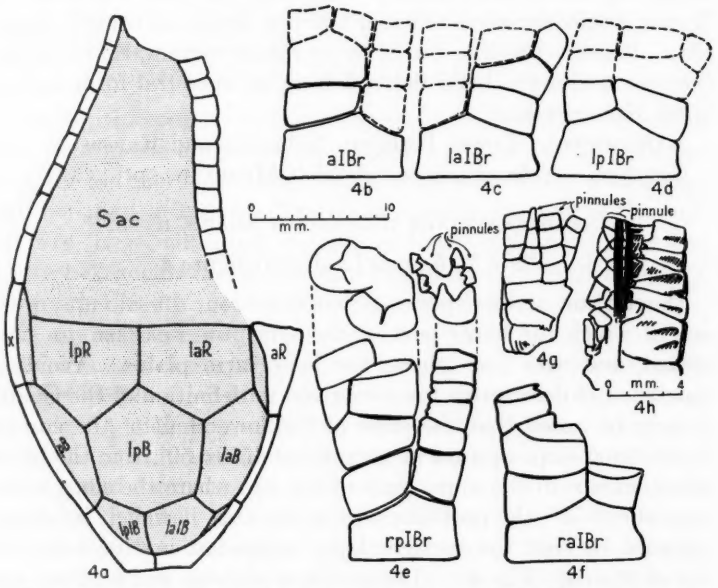


FIG. 4. Drawings of the calyx and arm structure of *Nebraskacrinus tourteloti*, n. sp., from the holotype specimen. *4a*, Median cross section through the pB and aR, showing the left half of the cup and anal sac (shaded) lying beyond the plane of the section; the bulge of the posterior portion of the calyx and the slightly higher elevation of the posterior radial than of the anterior is indicated; *4b–f*, Drawings of the arms, exterior views; *4g*, view from the right side of right-hand branch of the right posterior ray (see *4e*), showing pinnules attached to the inner edges of brachials; *4h*, Interior view of the same branch, showing very fine covering plates of the ambulacral groove of pinnule attached to the $IIBr_1$.

ness of these plates is only 0.6 to 0.8 mm. in the holotype specimen, but 1.3 to 1.5 mm. in one paratype. The outer ligament area of the radial facets, which is short, contains a moderately deep ligament pit, equal to one-half of the width of facet, and the remainder of the area is marked by denticles arranged normal to

the outer marginal ridge; the transverse ridge is sharp-crested and is bordered on the inner side by denticles that are short and obsolescent in the central portion near the central dorsal pit; the inner ligament area is distinctly concave, and due to absence of lateral ridges and oblique ridges, appears somewhat featureless, but a dorsal pit, intermuscular furrow, and intermuscular notch are distinct.

The RA is slightly the largest of the anal plates in the dorsal cup; it is pentagonal in outline, its lower right hand margin resting against the rpB. Anal x, resting on the pB, and rt, directly above RA, are large plates that project slightly above the summit of the RR. The anal plates of the cup are directly succeeded by tube plates arranged in alternating vertical series.

At the base of the IBr the transverse convexity is gentle, corresponding to that of the RR, but upward, this curvature is markedly increased so that at the level of the axillary IIBr the outer surface of the branches in a ray define practically a semicircle. An obtuse angle separates the curved outer surface of each branch from the sides of the branch, which are flat except for corrugations that serve for interlocking of adjacent arms. Beginning with the lowest IIBr, each nonaxillary arm segment bears a stout pinnule (Fig. 4g), and because of the close spacing of the arms, at least in the lower part of the crown, most of these pinnules lie parallel to the arms from which they arise and are very close to its ambulacral groove. The pinnules are flattened on the dorsal side, and except for their ambulacral groove, have a quadrangular cross-section; the segments are as long as wide, and some of them are almost half as wide as the arms to which they are attached. The minute covering plates of the grooves on the pinnules are visible in some cases (Fig. 4h); these are even-sized pieces about 0.1 mm. across, arranged in alternating series, about four rows longitudinally along the groove. The rows are convex and have the appearance of a string that is stretched along the position of the groove.

The two upper articular faces of the IBr are not of equal width, the wider facet supporting the branch that contains an axillary $IIBr_2$. Applying this criterion of the shape of the axillary IBr to the question of structure of the anterior and left posterior

rays, in which segments above the $IIBr_1$ are missing, it is indicated that the axillary $IIBr_2$ occurs respectively in the left and right branches of these two rays[4].

The top of the anal sac, representing an unknown, probably not large portion of its total original height, is broken off in the holotype specimen. The part that remains is approximately equal to the height of the dorsal cup, and like the cup, it has a regular conical form; a little above the summit of the RR it has a diameter of 13 mm., and at the top of the broken portion, the diameter is 7 mm. The plates composing the walls of the sac are arranged in columns that carry vertical grooves and ridges that, at least in part, are so aligned as to indicate places for reception of adjacent arms. A curious difference in the thickness of plates on opposite sides of the sac is revealed at the broken top of the sac in the holotype (Fig. 4a), plates on the anterior side being as much as 2.2 mm. thick, whereas those on the posterior side are as little as 0.7 mm. thick. The posterior wall of the sac slopes somewhat more than the anterior wall.

The surface of the dorsal cup, arms and sac is entirely smooth, the sutures are distinct but not impressed, and the contour of one plate joins smoothly that of its neighbors.

Measurements of the types of *N. tourteloti* are given in the following tabulation:

Measurements of Nebraskacrinus tourteloti, n. sp., in millimeters

	HOLOTYPE	PARATYPE 59021
Height of dorsal cup	17.7	18.0
Greatest width of cup	21.5	24.4[a]
Ratio of height to width	.82	.74
Diameter of stem impression	4.6	4.7
Length of basal plate (1pB)	11.0	11.3
Width of basal plate (1pB)	10.1	10.4
Length of radial plate (raR)	7.4	7.2
Width of radial plate (raR)	11.3	11.2

[a] Approximate.

[4] Paratype 59023, discovered after writing this description, shows unbranched IIBr at the left in the anterior ray and an axillary $IIBr_2$ at the right, followed by three IIIBr on one side and two on the other. The left posterior ray of this specimen shows four quadrangular IIBr in the left branch above IAx and three IIBr in the right branch, of which the $IIBr_3$ is axillary.

Remarks.—The dorsal cup of this new species differs so much in size and proportions from the conical cups of such forms as *"Poteriocrinites" macoupinensis* Worthen, *"P." lasallensis* Worthen, *Hydriocrinus? rosei* Moore and Plummer, and *Ulrichicrinus oklahoma* Springer, described from Pennsylvanian rocks, that detailed comparison is superfluous. The arms of these crinoids, except that last named, are not known.

Occurrence.—Grant shale member, Winfield limestone, Chase group, Big Blue series, Lower Permian, Nebraska and Kansas. Holotype collected by H. Allison Tourtelot, from the northwest corner of the southwest quarter of sec. 20, T. 1 N., R. 6 E., Nebraska. Paratypes collected by J. M. Jewett and R. C. Moore from sec. 1, T. 9 S., R. 4 E., about one mile east of Bala, Riley County, Kansas.

Types.—Holotype, collection of the Nebraska Geological Survey, University of Nebraska (number unassigned); plastoholotype, Kansas Univ., no. 46051; paratypes, Kansas Univ., nos. 59021, 59022, 59023.

Genus PACHYLOCRINUS Wachsmuth and Springer, 1879

Scaphiocrinus HALL, *1858*, Geology of Iowa, pt. 2, p. 550. ——— WACHSMUTH AND SPRINGER, *1879*, Revision of Palaeocrinoidea, pt. 1, p. 112; *1886*, pt. 3, p. 235.

Pachylocrinus WACHSMUTH AND SPRINGER, *1879*, Revision of Palaeocrinoidea, pt. 1, p. 115; *1886*, pt. 3, p. 242. ———SPRINGER, *1911*, Harvard Mus. Comp. Zoology, Mem., vol. 25, p. 145; *1913*, in Zittel-Eastman, Textbook of Palaeontology, p. 222; *1926*, U. S. Nat. Museum, Proc., vol. 67, art. 9, p. 70. ——— JAEKEL, *1918*, Palaeont. Zeitschr., Bd. 3, Heft 1, p. 62.

This genus is distinguished by the truncate bowl-shaped form of the dorsal cup, occurrence of three anal plates below the summit of the radials, separation of the outer parts of adjacent radial facets by well marked grooves, presence of a relatively long slender anal sac that may be recurved, circular cross section of the stem, (or subpentagonal near the dorsal cup), and structure of the arms, which are composed of uniserially arranged segments bearing slender pinnules and branching dichotomously at irregular intervals. The crown is generally three or more times the greatest width of the dorsal cup.

The IBB circlet consists of five plates that are mostly covered

by the stem impression; they are subhorizontal or flare slightly downward and are not visible in side view of the cup. The five BB are almost equal in size and are characterized by their strongly convex longitudinal profile, the down-flaring proximal edges forming part of the basal concavity of the cup and the up-flaring distal extremities being generally more nearly vertical than the slope of the RR. The RR are especially characterized by the inward curvature of the surface at the sides of the facets, so as to form grooves or notches between these plates at the upper margin of the cup. The facets are equal to the greatest width of the RR, or nearly so, but their outer parts are separated because of the flare of the RR. The three anal plates are normal in position, although in some specimens the RA separates anal x from contact with the pB plate. The arms are rounded dorsally; two or more divisions occur in each ray, but the branching does not appear to follow a uniform plan. Two IBr occur typically in each ray of the genotype species. The elongate anal sac is round or angular in cross section, and respiratory pores or slits occur between some of its columns of plates.

Remarks.—Approximately 100 species from rocks of Lower Carboniferous age have been assigned to *Pachylocrinus*, but it is clear that many of these do not belong to the genus as here characterized. Such forms as *"P." scoparius* (Hall) and *"P." spartarius* (Miller and Gurley), for example, have conical dorsal cups with the IBB plates flaring steeply upward and plainly visible in side view; the arm structure is like that of *Pachylocrinus*, but even though there are other correspondences with the genotype species, crinoids like those mentioned are believed not to belong in this genus. Kirk (1938, p. 168) has proposed the new genus *Linocrinus* to include several species that were formerly classed as representatives of *Pachylocrinus*.

Springer (1913, p. 222; 1926, p. 70) indicates the stratigraphic range of *Pachylocrinus* as basal Lower Carboniferous (Kinderhook) to Upper Carboniferous, but nowhere mentions any described species that is younger than Mississippian. He may have considered *Scaphiocrinus? washburni* Beede, from upper Pennsylvanian beds of Kansas, as belonging to *Pachylocrinus*,

but this is doubtful. As a matter of fact, unless restriction is made to crinoids having two IBr, as in the genotype species, the genus ranges nearly to the top of the Lower Permian (Wolfcamp, *Pseudoschwagerina* zone), for it is represented by beautifully preserved specimens in our collection from the Chase group in Kansas (here described as *Pachylocrinus colubrosus*, n. sp.) that may be conspecific with the crinoid described as *Erisocrinus lutana* Boos (but apparently belonging to *Pachylocrinus*) from the Luta limestone of southern Kansas and northern Oklahoma.

Careful comparative study of the numerous crinoids that have been considered to belong to *Pachylocrinus* is much needed, and it is certain that revisions are necessary. Springer's (1926, p. 70) proposal to assign to *Abrotocrinus* Miller and Gurley pachylocrinids with a pentagonal stem is not at all acceptable, for the genotype species of *Pachylocrinus* has a pentagonal stem form next to the cup.

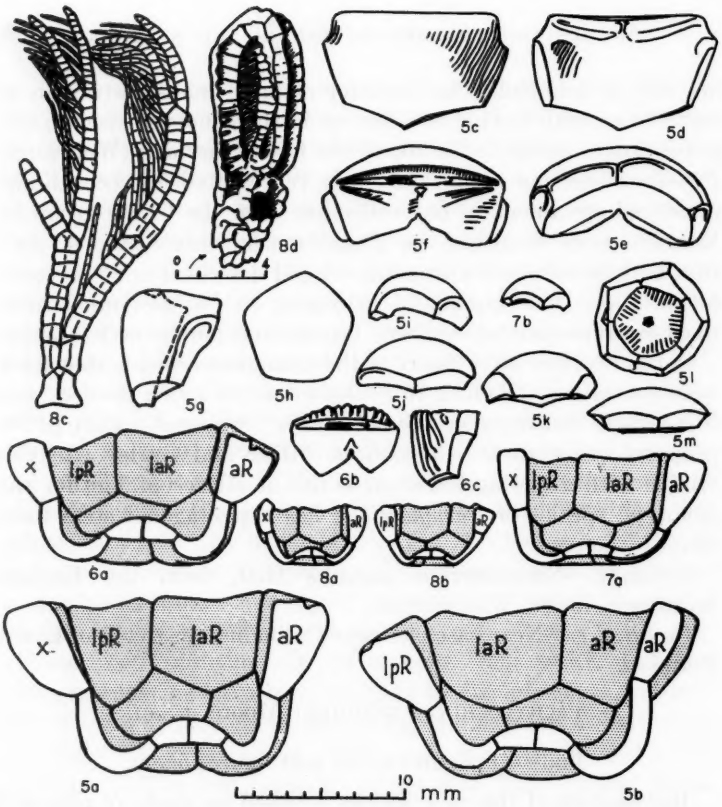
Genotype.—*Scaphiocrinus aequalis* Hall, from the Keokuk limestone, lower Mississippian.

Occurrence.—Near base of Lower Carboniferous to top of Lower Permian.

PACHYLOCRINUS MCGUIREI Moore, n. sp.

Plate VI; figures 6–16; text figures 5a–m.

Recognition of this new species is based on study of nine well preserved dorsal cups and crowns, together with fragmentary remains of several other specimens. There is little difference in the size and general appearance of the cups, but study indicates the existence of noteworthy variation in some characters, as will be pointed out in comment on certain individuals. The most nearly complete crown is designated as a paratype, rather than the holotype, because it departs appreciably from the norm of the species, and may even be specifically distinct. The following description is based on the holotype and five paratypes that show essentially identical dorsal cups, supplemented by specimens of the stem and upper arms that were found with the holotype and, although disconnected, probably belong to it. The remaining paratypes will be considered separately.



FIGS. 5–8. Drawings of Upper Pennsylvanian and Lower Permian species of *Pachylocrinus*. *5a*, Median cross section of the dorsal cup of *Pachylocrinus mcguirei* through the pB and aR, showing the left half of the cup beyond the plane of the section (shaded), based on the holotype specimen; *5b*, a similar section drawn through the lpR and raB of the holotype; *5c–g*, views of dissociated radial plate belonging to *P. mcguirei*, from the exterior, interior, top, bottom, and side (median profile dotted); *5h–k*, views of a typical basal plate of *P. mcguirei*, from the exterior, side, distal edge, and proximal edge; *5l–m*, infrabasal circlet of *P. mcguirei*, from the exterior, and the side. *6a*, Median cross section of the dorsal cup of *Pachylocrinus bellirugosus*, n. sp. through the pB and the aR, based on the holotype; *6b–c*, top and side view of a radial plate (rpR) of the holotype. *7a*, Median cross section of the dorsal cup of *Pachylocrinus twenhofeli*, n. sp., through the pB and aR, based on the holotype; *7b*, side view of a basal plate. *8a*, Median cross section of the dorsal cup of *Pachylocrinus colubrosus*, n. sp., through the pB and aR, based on the holotype; *8b*, a similar section through the lpR and raB; *8c*, arms of the anterior ray of the holotype, showing keeled Br and long pinnules; *8d*, side view of the coiled anal tube of the paratype specimen, showing supposed anal vent near the proximal part.

Dorsal cup truncate bowl-shaped, with a slight but distinct basal concavity; the height of the cup is a little less than one-half of the greatest width. A distinctive feature of the shape of the cup is the strongly marked difference between the lower and upper parts, the basal half resembling a rounded bowl with approximately vertical upper edges, the upper half flaring sharply outward (Figs. 5a, b), with sides that slope evenly but in such fashion as to produce strongly marked scallops in a horizontal plane. This bipartite aspect, and especially the splay-toothed appearance of the radial circlet, serves readily to separate cups of this species from most others.

The IBB circlet is pentagonal in outline and only a little larger than the proximal stem segment; the outer surface of the plates is horizontal but on the inside of the cup the IBB form a low cone (Fig. 5m). The stem impression, which is subpentagonal with rounded points, is slightly to rather strongly concave; it is marked by about 35 crenellae that are arranged in five distinct groups, for the alinement of the grooves and ridges on any one IB is nearly the same but this is different from that of neighboring IBB (Fig. 5l). When dissociated from other plates of the cup, the suture edges of the IBB circlet are seen to be rather strongly hollowed, evidently for reception of ligament fibres; each IB bears a pit on each of its two distal edges, and each side of the IBB pentagon, therefore, carries a pair of pits. The plane of the distal sutures, as defined by the narrow rim of the pits, intersects the horizontal outer surface of the circlet obliquely, but it is nearly normal to the sloping inner surface of the circlet.

The five BB do not differ perceptibly in size, although the rpB is actually a trifle broader than the others. The outline of this plate, and of the pB in some specimens, is hexagonal instead of pentagonal, like all the rest. The length exceeds the width of the plates only slightly. The proximal portion of the BB slopes downward, forming the sides of the shallow basal concavity. The surface curves strongly in longitudinal direction so that it becomes tangent to the basal plane of the cup at an approximate distance of only one-fourth of its length from the proximal edge; the distal part of the plates is subvertical and may even curve

slightly inward. Each B is rather strongly convex transversely, as well as longitudinally, which produces a bulbous appearance and makes the sutures impressed (Figs. 5h–k). The suture faces of the BB are hollowed in a manner like that described for the IBB, but the pits are larger; there is one depression on each suture face except the proximal one, which carries two.

The RR are pentagonal in outline, but because of the outward projection of the facets, which produces prominent notches between the upper margin of the RR, these plates appear heptagonal when viewed normally to the middle of the outer surface (Fig. 5c). The longitudinal profile is gently curved or nearly straight (Fig. 5g), but a strong, fairly regular transverse curvature produces a scalloped outline in the upper part of the dorsal cup. The length of each R is almost exactly one-half of the width, measured along the surface of the plates, but because of the curvature that has been noted, the linear distance between the upper angles of an R is only slightly more than three-fourths of the width measurement that includes curvature. Furrows between adjacent RR are deep, and these are prolonged at the summit of the cup so as to divide the facets, which rather falsely, appear distinctly narrower than the greatest width of the RR. The length of the facets is approximately one-half of their width (Fig. 5f). Their plane slopes gently outward; they are shorter and the outward slope is less pronounced than in hydreionocrinid genera. The outer ligament area is short, moderately deep, and its middle portion is occupied by a prominent ligament pit that is half as wide as the facet; the outer marginal ridge is low but distinct, and the adjacent part of the ligament area carries prominent denticles arranged normally to the ridge (Fig. 5f). The transverse ridge is moderately elevated and sharp-crested in the portion adjoining the ligament pit, but the lateral extremities are somewhat broader and the summit is marked by narrow slit-like incision. The inner ligament area is not deeply excavated; oblique fossae are prominent, a central pit confluent with the intermuscular furrow is observed, and the muscle areas are nearly plane. Denticles like those of the outer ligament area do not appear on the transverse ridge or on the inner ligament area.

A feature that appears to be characteristic of this species is a noticeable difference in the elevation of the summit portions of different RR above the basal plane of the cup, and, correlated with this, a variation in their radial distance from the vertical axis through the center of the stem impression. The rpR is lowest and farthest from the axis of the cup; the aR is highest and closest to the axis. Thus, the cup has a distinct asymmetry of form. Average measurements are given in the following tabulation:

Measurements indicating asymmetry of the dorsal cup of Pachylocrinus mcguirei, n. sp., in millimeters, average of five specimens

	rpR	raR	aR	laR	lpR
Height of middle of outer marginal ridge of facet above basal plane of cup	6.8	7.4	8.6	8.2	7.8
Distance radially from vertical axis through center of stem impression to middle point on outer marginal ridge of facet	12.0	10.0	8.6	9.0	10.2

The anal plates in five specimens, including the two non-typical examples that will be noted separately, have the plates in normal arrangement, with the RA resting against the rpB, the anal x plate resting on the truncated tip of the pB, and the right tube plate (rt) directly above the RA. The remaining four types differ in that the RA extends upward and to the left far enough to separate anal x from contact with pB, and in this case the RA touches both of the posterior RR. The three plates of the anal series are almost equal in size, but the RA and x are a little larger than rt.

The arms are long, slender, strongly rounded on the dorsal side, and are composed of uniserially arranged slightly trapezoidal segments that bear long pinnules. The first primibrach (IBr_1) is axillary in all rays. An isotomous division of the arms occurs at irregular intervals higher in the crown. None of the available specimens shows the complete arm structure in any of the rays, but fragmentary remains indicate that the length of the arms exceeds 80 mm., which is approximately eight times the

height of the dorsal cup. Several portions of arms belonging to the upper part of the crown are unbranched for distances of 20 to 25 mm.; the diameter of these arms is 2 to 2.5 mm., and there are 16 to 25 segments between axillary plates. Attached pinnules are about 1 mm. in diameter and at least 15 mm. long.

One of the specimens (paratype 46047) affords information concerning the nature of the anal sac. This is a slender curved tube, the terminal part of which appears to be sharply curved back on itself so as to bring the distal extremity to a position near the base. The tube is laterally compressed and is apparently made up of four columns of plates, the two rows on the outer, convex side of the curved tube each bearing low narrow spines aligned to form a pair of denticulate keels with a shallow furrow between them. The sides of the tube are marked by very prominent respiratory slits running transversely to the axis of the tube. The plates on the inner, concave side of the bent tube do not appear to be keeled nor to bear pores except along the line of suture with the two outer rows of plates. The recurved distal part of the tube is slender and is not sufficiently well preserved to show the location of the anal vent. The nature of this sac strikingly resembles that of the crinoid described as *Pachylocrinus scoparius* (Hall) by Springer (1926, p. 67, pl. 16, fig. 2) from upper Chester beds in Kentucky, but the conical form of the dorsal cup in this species indicates that it is not properly assigned to *Pachylocrinus*. It is referred by Kirk (1938, p. 165) to his new genus *Eratocrinus*, which has a dorsal cup with a concave base, but this assignment is equally erroneous if the form of the dorsal cup has any generic significance.

The stem is circular in outline and distinctly annulated, for nodals with rounded longitudinal profile project sideward beyond the edges of wafer-like internodal segments, and typically these two types of segments occur in alternation so as to form pairs; about six or seven of these pairs occur in a longitudinal distance of 6 mm. The stem segments are pierced by a very small subcircular lumen and each articulating face bears about 30 short crenellae. On the proximal segments, there is indication of a pentagonal outline in the arrangement of the crenellae, but this is not observed on other segments.

Measurements of some of the types of *P. mcguirei* and of other species from upper Pennsylvanian and Permian beds described in this paper are as follows:

Measurements of Pachylocrinus mcguirei, n. sp., P. twenhofeli, n. sp., P. colubrosus, n. sp., and P. bellirugosus, n. sp., in millimeters

	P. MCGUIREI					P. TWENHOFELI HOLOTYPE	P. COLUBROSUS HOLOTYPE	P. BELLIRUGOSUS HOLOTYPE
	Holotype (46043)	Paratype (460417)	Paratype (46044)	Paratype (46041)	Paratype (46046)			
Height of dorsal cup	9.6	9.1	9.7	9.5	5.2	6.1	3.0	6.5
Greatest width of cup	20.1	21.0	22.2	22.8	14.7	12.0	6.8	12.5
Ratio of height to width	.48	.43	.44	.42	.35	.51	.44	.52
Height of basal concavity	1.7	1.0+	3.3	1.5+	0.6	0.5	0.4	?
Width of IBB circlet	5.2	6.0	5.2	3.7	3.9	3.7	2.2	?
Width of stem impression	3.6	3.3	3.0	3.0	2.0	2.3	1.6	3.4
Length of basal plate (raB)	8.5	7.5	9.0	9.0	6.0	5.5	3.0	5.0
Width of basal plate (raB)	7.5	7.4	8.5	8.1	5.7	5.0	2.7	5.4
Length of radial plate (aR)	5.5	5.9	6.0	7.4	4.0	5.0	2.2	3.6
Width of radial plate (aR)	11.1	11.1	11.9	12.0	7.9	7.6	3.6	8.2
Length of transverse ridge (aR)	7.5	7.5	7.9	8.2	5.5	6.0	2.7	6.7

A crown that is classed as a paratype (no. 46041) (Plate VI, fig. 15) differs from the other examples that have been described in the much reduced size of the IBB circlet, the lower convexity and less accented differentiation of the BB circlet from that of the RR, and some variations in structure of the arms. This specimen is evidently related closely to the others, but at first it was thought probably to represent a different species. It has seemed preferable, however, to interpret it as a variant of *P. mcguirei*. The size and general structure of the dorsal cup is the same as in that species, and the isotomous division of the arms at slightly irregular intervals is similar, but in the left posterior ray there are four quadrangular IBr below the first axillary plate, and in the right posterior ray the first branching occurs on the second IBr. The surface of the plates is smooth except for faint irregular corrugations like those observed on some specimens of normal aspect.

Another specimen (paratype 46044) (Plate VI, fig. 14), consisting of a complete dorsal cup and lower brachials in a few of the rays, closely resembles the typical specimens in the general shape of the dorsal cup and the bulbous nature of the plates. It is distinguished from them, however, by the unusual depth of the basal concavity, and by a very definite pattern of low corrugations on the plates that gives them an ornamented appearance. The greater depth of the basal concavity is due chiefly to the pronounced curvature of the proximal portions of the BB, which is associated with the somewhat unusually bulbous nature of these plates. The corrugated ornamentation is the same in nature as the fainter markings on the plates in several of the typical specimens and may be regarded as a mere individual variation.

Fragmentary remains.—Dissociated plates of the dorsal cup, fragments of arms, and pieces of stem belonging to *P. mcguirei* are recognizable in the large collection of fragmentary crinoidal remains obtained from the Brownville limestone near Strohm. Description of some of these fragments is useful because it may aid in identification of this crinoid from other localities.

Four IBB circlets, which in first study were not recognized as belonging to this species, are now identified definitely both from comparison with type specimens of *P. mcguirei* and by dissection of a fragmentary specimen of this crinoid so as to show completely the nature of the IBB circlet (see Plate VI, figs. 7–9). The rounded-pentagonal stem impression occupies all but the distal portion of the exterior surface of these plates, which extends horizontally outward from the stem area (Figs. 5l, m). The suture faces, which are moderately to strongly excavated, define planes that intersect the exterior of the circlet obliquely, and all of these faces are visible in a view normal to the stem impression. The interior surface of the circlet is smoothly and gently convex. The greatest width of the circlet ranges from 6.0 to 6.9 mm., the height 2.3 to 2.8 mm., diameter of stem impression 3.6 to 4.3 mm., diameter of the subpentagonal lumen 0.4 mm. These IBB disks, which may be designated according to nomenclature of separated ossicles, (Moore, 1939), as *Pentexobasis mcguirei*, are readily distinguished on basis of the described characters from other IBB circlets that are found in the Brownville limestone.

Two dozen or more basal plates are identified as belonging to *P. mcguirei* because they correspond in shape, size, surface markings, and the excavated character of the suture faces to the characters of these plates seen in articulated cups. (Figs. 5h–k). Isolated basal plates, for which the ossicle designation *Schedaglaopolygonum mcguirei* may be employed, are readily distinguishable from the many other plates occuring in the Brownville limestone (see Plate VI, figs. 10, 11). Their shape, moderately small size, strong convexity, and thickness aid in identification. The surface shows faint to fairly distinct low corrugations, and there is typically a very narrow border next to the suture markings that is differentiated from the remaining curved surface of the plates. The proximal portions of these plates is identified by its much more abrupt curvature, and commonly there is an indentation of the middle part of the steep slope in the proximal region. The proximal suture face carries two shallow ligament pits; the other sutures carry similar but larger depressions that are bounded by a very narrow rim.

Some five dozen dissociated radial plates that represent this species have been collected from outcrops of the Brownville limestone near Strohm. Individual ossicles of this type may be designated by the term *Pachylarthrum mcguirei* (Figs. 5c–g). They are differentiated from other RR, first by the relatively narrow articular facets, for an extension of the outer face of the plate reaches around the edges of the transverse ridge to the inner margin of the facet. The longitudinal profile is straight, except for a shoulder near the facet, but the transverse curvature is strong. A narrow rim, like that on the corresponding BB plates, is seen on the proximal and lateral edges of these plates. The four suture faces, located on the sides and proximal edges of the plates, are moderately to rather strongly excavated. The facet shows characters corresponding exactly to those described in discussion of the dorsal cup of *Pachylocrinus mcguirei.*

A few specimens of isolated anal plates representing this crinoid have been found. They are distinguishable from the basal plates only by the somewhat lower curvature of the outer surface and absence of a differentiated proximal edge. In dealing with isolated ossicles, they would naturally be classified with the basals.

Segments of arms, many of them showing attached pinnules, found especially at the locality five miles west of Strohm, are unhesitatingly identified as belonging to *P. mcguirei*. The strongly rounded cross-section, uniserial arrangement of slightly trapezoidal segments, and the relatively long stout pinnules are distinguishing features, but it is very doubtful whether such fragments could be identified with any confidence if these were not associated with undoubted remains of *P. mcguirei*.

Stem segments (*Cyclocyclopa mcguirei*) can be separated from other types of stems seen in the Brownville and other upper Pennsylvanian limestones on the basis of the arrangement of alternating rounded, laterally projecting segments, and the intervening, wafer-like smaller segments (fig. 12).

Remarks.—The form of the cup and peculiarities of the plates observed in *P. mcguirei* correspond closely to characters observed in the genotype species, *P. aequalis* (Hall) from the Keokuk limestone, Crawfordsville, Ind. A well preserved topotype specimen of the Mississippian species has been made available to me through kindness of Dr. R. S. Bassler. The upper Pennsylvanian species here described is distinguished by the stronger convexity of the plates, their different surface markings, and by the somewhat less numerous branching in the arms. The first axillary plate in the arms of *P. aequalis* is the IBr_2, but in *P. mcguirei* it is the IBr_1. *P. mcguirei* is distinguished from two new species of *Pachylocrinus* from the Missouri series in Texas, especially on characters of the shape of the cup and markings of the plates. A crinoid from the Luta limestone of southern Kansas and southern Oklahoma, described by Margaret Fuller Boos, as *Erisocrinus lutana* is judged from the description and illustrations to belong to *Pachylocrinus*. Assuming that Boos's species should be designated as *Pachylocrinus lutanus*, though I have not seen the type, it may be noted that this Permian form is different from *P. mcguirei* in the shape of the cup, especially its less prominent splay-toothed appearance, and in its much smaller size.

This interesting upper Pennsylvanian crinoid is named for Mr. Paul McGuire, Fairfax, Okla., who collected most of the crinoids on which this paper is based, and to whose active inter-

est in fossils is due the discovery of the Brownville crinoid fauna in Osage County, Oklahoma.

Occurrence.—Upper member of the Brownville limestone Wabaunsee group, Virgil series, Pennsylvanian; Loc. 4604; five miles west of Strohm, Okla. Collected by Paul McGuire.

Types.—Holotype, McGuire collection, no. 46043; paratypes, nos. 46041, 46042, 46044, 46045, 46046, 46047, 460413, 460416, 460417, 460418 (stems, arm fragments); 460419a–z, a′–d′ (basals); 460420 a–z, a′–z′, a″–d″ (radials); 460421a–c (IBB circlets) Plastotypes of cups, Kansas Univ. same numbers.

PACHYLOCRINUS BELLIRUGOSUS Moore, n. sp.

Plate VII, figures 5a–c; test figures 6a–c.

Description of this handsomely decorated crinoid is based on a single somewhat flattened specimen that shows the dorsal cup and lower part of the arms. The height of the cup is about one-half of the greatest width, and the shape of the cup is characteristic of the genus.

The IBB circlet is located in a shallow basal concavity; the greatest width of this circlet can be little if any greater than the diameter of the stem, for the attached few proximal segments of the stem conceal these plates entirely.

The BB have a strong longitudinal convexity, the most abrupt curvature being in the proximal region, which forms the sides of the basal concavity and touches the basal plane of the cup (Fig. 6a); the transverse curvature of these plates is about the same as the arc of the circle that each subtends, except for border areas that curve abruptly so as to produce strong furrows in the position of the sutures, giving the plates a somewhat bulbous appearance.

The RR slope upward and outward evenly at an angle that is less steep than the distal parts of the adjacent BB; the longitudinal profile of the RR is nearly straight, but the transverse curvature is sufficient to produce distinct furrows in the position of the interradial sutures. Notches between the RR at their summits are visible but are less prominent than in several other species of *Pachylocrinus*. It has been possible to remove the

arms from their contact with the RR in two of the rays (rpR, laR) so as to see clearly the nature of the articular facets (Figs. 6b, c). The outer and inner ligament areas lie essentially in the same plane, at an angle of almost exactly 90 degrees from the line connecting the proximal tip with the midpoint of the outer marginal ridge of the facets; the outer ligament area contains denticles along the outer border and except for the deep ligament pit, which occupies about one-half of its length and width, is only slightly depressed; the transverse ridge, unmarked by denticles, is moderately sharp-crested, and although its length is equal, or nearly equal, to the greatest width of the RR (measured straight across rather than along the curved surface) the position of the ridge is set outward slightly from the summit of the interradial sutures. The inner ligament area shows well marked oblique furrows, a small dorsal pit, and a shallow intermuscular notch.

Arrangement of the three plates of the anal series is normal except for the slight separation of the anal x from the distal tip of pB; the RA touches the rpB and is followed above by anal x and rt.

The sutures between the RR and the IBr are gaping. The arms branch equally in each ray on the IBr_1, and since not more than two IIBr are preserved in any one of the secondary branches, the position and nature of other bifurcations, presumed to exist, are not known. The arms are moderately well rounded externally, and in the IIBr their width is about equal to thickness, giving articular surfaces a circular outline except for the notch of the ambulacral furrow.

The round stem has a strongly annulated appearance, the midlength of each segment being strongly convex, and this bulging part carries tubercles spaced about 0.5 mm. apart; the nature of the crenellae is not well shown, but a subpentagonal lumen, 0.4 mm. in diameter, is visible. Observations concerning the stem are based on three attached proximal segments at the base of the of the cup. No evidence concerning the anal sac is found.

The nature of the surface markings of this crinoid and the well marked furrows along each of the suture, attract attention before

almost any other character. The decoration consists of narrow, sharp-crested ridges and of tubercles. Some plates, chiefly the RR, are ornamented almost entirely by ridges, trending longitudinally, some of which are straight and undivided, others slightly crooked and bifurcated. The BB are similarly decorated except that numerous tubercles tend to make appearance in the middle and distal areas. Ridges and tubercles, arranged in a somewhat definite pattern, give a distinctive appearance to the outer surfaces of the brachial segments. The height of tubercles and ridges is 0.2 to 0.5 mm.

Measurements of the cup of this species are given on page 211.

Remarks.—In size, shape, and some other features, the cup and lower arms of *P. bellirugosus* correspond almost exactly to those of *P. twenhofeli*. The plates of *P. bellirugosus* are much thicker and the strongly marked surface ornamentation serves readily to distinguish it, not only from Pennsylvanian and Permian species, but from those of the Lower Carboniferous rocks. Although the upper part of the arms and the nature of the anal sac are not known, this species is assigned to *Pachylocrinus* without more question than in the case of species such as *P. mcguirei*.

Occurrence.—Middle part of the Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous), near Emporia, Kans. Unfortunately, the precise horizon and locality from which the type specimen of this species was obtained are not recorded. The crinoid was found by Mr. Alva J. Smith (now deceased), former county engineer of Lyons County, and came into my hands in 1916 with the notation "Upper Pennsylvanian near Emporia, Kansas."

Type.—Kansas Univ., no. 60251.

PACHYLOCRINUS TWENHOFELI Moore, n. sp.

Plate VI, figures 1–4; text figures 7a, b.

Dorsal cup truncate bowl-shaped, with a shallow basal concavity and flaring sides, height about one-half of greatest width of cup. IBB circlet small, at top of basal concavity, almost

entirely concealed by the proximal segments of the stem. From their proximal margin, the BB flare slightly downward to the basal plane of the cup but throughout most of their length they slope evenly and rather strongly upward; the transverse convexity is sufficient to produce a shallow furrow in the position of the interbasal sutures.

The surface of the RR is straight longitudinally, except within 1 mm. or less of the margin of the facets, where an abrupt inward curvature is noted (Fig. 7a). The transverse curvature is even but is distinctly greater than that of one-fifth of a circle having the radius of the cup at the level of the RR; this gives the cup a scalloped outline in dorsal or ventral view; the furrows along the interradial sutures are accented by notches at the upper angles of the RR. The facets, like those of other species of the genus here described, are characterized by the short length of the outer ligament area, with numerous denticles along the outer edge and with a relatively very wide deep ligament pit. The arrangement of plates in the posterior interradius is similar in all of the six observed specimens, with the RA in contact with the rpB, and with anal x resting on the distal tip of pB; the area of the anal plates appears not to be depressed.

The sutures between the RR and IBr are slightly gaping. The first IBr in each ray is an axillary plate that is wider than long and that is marked especially by broad depressions on each side of a short median keel; near the distal extremities the keel divides and is continued on the IIBr. No more than two of the IIBr are preserved in any of the secondary branches, but these segments appear to be slightly trapezoidal in form. A fragment of arms from the upper part of the crown of a specimen undoubtedly belonging to this species shows slender distinctly wedge-shaped segments with attached long slender pinnules, the length of individual pinnules being at least 9 mm.

The stem is round and annulated, with alternately disposed segments of different width and thickness; the rounded bulge that girdles each segment occupies the full length of the larger columnals, but in smaller ones it may fill only part of the length. A few of the proximal columnals are attached to each of the dorsal

cups and the collection contains two separated stem fragments containing 14 and 16 ossicles, respectively. The articular surfaces on each columnal are marked by about 35 moderately short crenellae and at the center is a sub-pentagonal lumen, 0.3 to 0.4 mm. in diameter. Next to the cup the outer ends of the crenellae define a pentagon with rounded angles, although even the first columnal below the cup is perfectly circular in outline. A short distance from the cup the outer ends of the crenellae define a circle. One internodal segment occurs between each successive pair of nodals, but each second nodal is intermediate in size between the internodals and the largest nodals; thus, the columnals may be arranged readily into groups of fours that follow the same pattern. Slender round cirri, about 0.7 mm. in diameter, and up to 3.7 mm. in length, are attached to several of the nodals, both the main nodals and the smaller ones, although the latter generally, and the former occasionally, lack these.

The surface of plates of the dorsal cup and arms and stem is perfectly smooth.

Measurements of the holotype, which closely matches other specimens in size, are given on page 211.

Remarks.—The proportions and general form of the dorsal cup and the smooth surface of *P. twenhofeli* are like those of *P. mcguirei*, but the latter is a much larger, coarser species with prominently developed splay-toothed appearance of the RR; the surface of the brachials in *P. mcguirei* is smoothly rounded and not keeled. *P. colubrosus*, which is a smaller, more delicate form than *P. twenhofeli*, resembles this species in the appearance of the arms, but the cup of the smaller species is marked by well defined pits at the angles of the plates.

Occurrence.—Ft. Riley limestone member of the Barneston formation, Chase group, Big Blue series, Lower Permian; loc. 744, near center of sec. 33, T. 7 S., R. 6 E., near Walsburg, Riley County, Kans. Collected by W. H. Twenhofel.

Types.—Holotype, Univ. of Kansas no. 744-1; paratypes, nos. 744-2, 744-3, 744-4, 744-5, 744-6 (dorsal cups) and 744-7, 744-8 (stem fragments).

PACHYLOCRINUS COLUBROSUS Moore, n. sp.

Plate VI, figures 5a–c; Plate VII, figures 6a–c; text figures 8a–d

Crown subpyriform, about ten times the height of the dorsal cup; the height of the crown in the holotype measures 33.5 mm. and the width across the upper part of the outspread arms is about the same. The dorsal cup has a small truncate bowl-shaped form, with height a little less than the greatest width; a small but very distinct basal concavity that is almost filled by proximal segments of the stem is present (Figs. 8a, b). The distal tips of the IBB are barely visible beyond the edge of the stem. The surface of the BB curve with extreme abruptness from the downward flaring part at the proximal end to the upsloping portion that includes almost all of the area of these plates.

The length of the RR is two-thirds of their width; their surface is gently convex longitudinally and transversely; small notches occur at the summit of the interradial sutures, but the outline of the cup in dorsal or ventral view is not distinctly scalloped. The articular facets are essentially like those of other species of the genus that have been described. The posterior interradius is not depressed, and plates of the anal series have a normal arrangement, with the RA in contact with the rpB and the anal x resting on the truncated tip of the pB.

A proximal stem segment that is attached to the holotype shows that columnals are circular in outline, the articular surface bearing about 20 crenellae that are arranged with the outer edges defining a circle with five distinct segments; the sub-pentagonal lumen has a diameter of 0.15 mm. The surface of the dorsal cup is smooth, the sutures are very distinct but not impressed, and there are well marked small pits at angles between the plates.

The arms are nearly completely shown in the holotype specimen and are partly shown in the paratype. Isotomous division occurs on the IBr_1 in each ray and the branches thus formed divide similarly at one or two higher points in the crown. The number of IIBr ranges from 6 to 9 and about 12 to 14 IIIBr normally occur between bifurcations, but in some cases where a

third subdivision of the arms is lacking the number of these is larger. The upper part of some of the rays show 12 to 15 IVBr. The arms are keeled throughout their length. The outline of the segments is slightly to distinctly trapezoidal. Long slender pinnules, up to about 12 mm. in length are attached to Br above the IBr, and this gives to the arms a decidedly feathery appearance (Fig. 8c).

Especially interesting, and shown by both of the types, is the nature of the anal sac, which has the form of a tube with angular cross section, rising subvertically within the circle of the arms to a height of about one-third that of the arms, and then curving sharply, so that the distal part of the tube runs downward parallel to the proximal part (Fig. 8d). The exterior of this loop is formed by a double column of plates that meet without intervening respiratory slits, forming a channel that is bordered by two sharp, locally nodose keels. The two sides of the tube are marked by rows of plates with prominent slits, and the depressed central part, embraced by the coil, shows columns of plates with slits. The sac of the paratype, which is little larger than that of the holotype, shows a depression surrounded by plates that seems to represent the anal vent (Plate VI, figure 5c). If that is the case, the opening appears to be connected with the proximal part of the tube, rather than the distal part, and this suggests that the main part of the tube functions mainly in connection with respiration or the water circulatory system rather than as covering for an elongated convoluted gut. Lateral union of the plates in the thin depressed central region with those of the surrounding main part of the tube indicates that these are functional parts of the main upward and downward portions of the tube rather than, as suggested by appearance of sharp curvature near the distal end, just above the anal vent, of a further upturning of the tube in the central region.

Measurements of the holotype are given on page 211.

Remarks.—This species is readily distinguished from any of those previously described in this paper by its small size and by the fairly even contour of the cup, with small pits at the junction

of the plates. Closest similarity appears to exist between *P. colubrosus* and the crinoid described from the Luta limestone of southern Kansas as *Erisocrinus lutana* Boos. The genus *Erisocrinus* is so dissimilar to *Pachylocrinus* that the suggested comparison would seem almost absurd were it not for the fact that the published figures and description of the arm branching show plainly that the Luta crinoid under discussion is not an *Erisocrinus*. I have not been able to study the types of *E. lutana* and the figures do not show whether or not an anal plate or plates are really absent, as is to be inferred from the author's assignment of this species to *Erisocrinus*. If *E. lutana* belongs to *Pachylocrinus*, as I am inclined to think, it corresponds in almost every way to *P. colubrosus*, except in having a delicate pebbled surface ornamentation instead of smooth plates, and in having perhaps slightly more constricted axillary primibrachs.

Occurrence.—The two types of this species are on a single small slab of limestone that was collected a few years ago by a student (name unrecorded) in the Department of Geology at the University of Wichita. The only available data are its reported discovery in the vicinity of Augusta, Butler County, Kans., and information obtained from examination of the lithology of the rock. There are quarries in the Ft. Riley limestone near Augusta and this formation is most prominently exposed in that vicinity. The rock corresponds lithologically to the Ft. Riley, and if the specimens did not come from this horizon, unquestionably they belong near to it. The specimens were turned over to me by Prof. J. M. Jewett, formerly of the University of Wichita and now of the geology faculty of the University of Kansas. At the time the piece of limestone was given to me, only a few arms and a small portion of the anal sac of a crinoid were visible, the dorsal cup being weathered away; this incomplete individual is designated as a paratype. In preparing the specimen, another individual that had been entirely concealed in the rock, was uncovered and this is chosen as the holotype.

Types.—Holotype, Kansas Univ., no. 59091, paratype 59092.

Genus PLAXOCRINUS Moore and Plummer, 1938

Plaxocrinus MOORE AND PLUMMER, *1938*, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (*1937*), p. 277.

This genus was differentiated from other Upper Carboniferous crinoids having three anal plates in the dorsal cup, primarily on the basis of the shape of the cup. The bottom of the cup is very gently concave, and the five IBB are not visible in side view of the cup. The proximal parts of the BB are included in the basal depression, the middle parts are tangent to the basal plane of the cup, and the distal parts are visible in side view. The proximal portions of the RR generally touch the basal plane. The plane of the articular facet, as in other hydreionocrinid genera, slopes distinctly but not steeply outward.

Remarks.—The genus most closely related to *Plaxocrinus* is *Perimestocrinus*, distinguished by the proportionally deeper bowl shape of the cup and the more abrupt walls of the basal concavity. Also similar are cups with flat or very gently rounded base, defined as belonging to new genera in a paper on Texas crinoids (Moore and Plummer, 1939). Information concerning the arms of *Plaxocrinus* and evidence concerning the anal sac are given in the following description of *P. politus*. The arms branch isotomously on the IBr_1 and each secondary branch divides equally on the $IIBr_4$ to $IIBr_6$; in each known case, including some undescribed species, the axillary primibrach is spine-bearing.

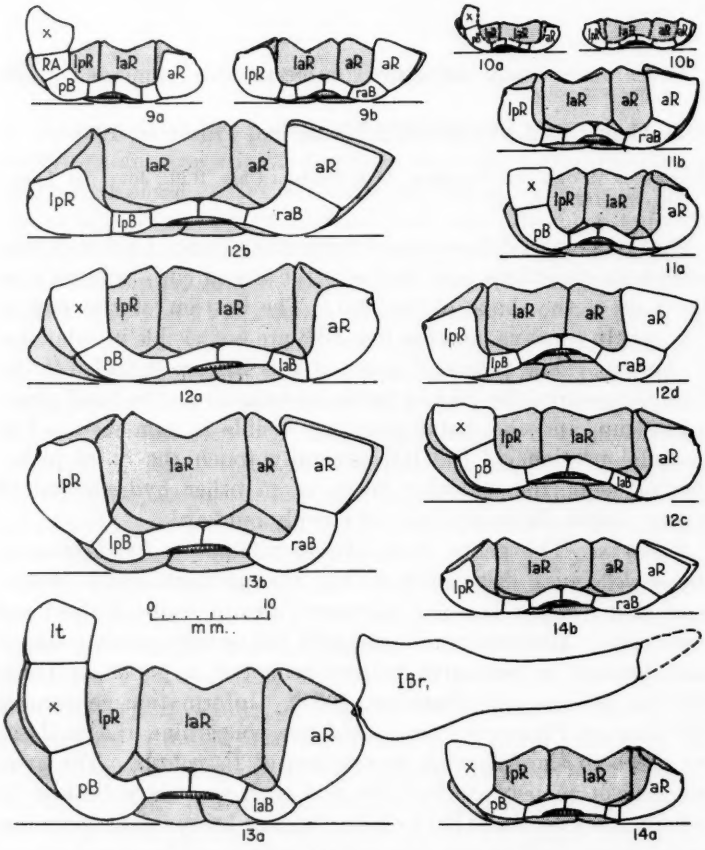
Occurrence.—Morrow to Virgil series, Pennsylvanian (Upper Carboniferous), central United States.

Genotype.—*Hydreionocrinus crassidiscus* Miller and Gurley (see Figs. 9a, b; 15g), Missouri series, Kansas City, Mo.

PLAXOCRINUS POLITUS Moore, n. sp.

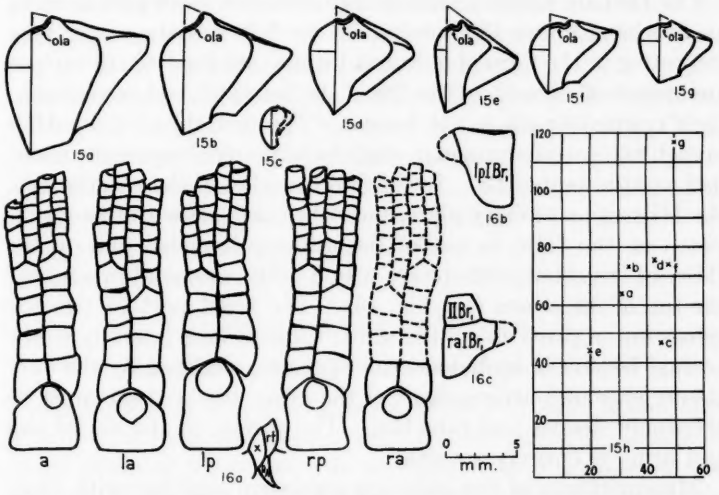
Plate VIII, figures 5a–c; text figures 10a, b, 15c, 16a–c

Crown slender, sub-cylindrical in form, its height nearly three times the greatest width of the dorsal cup, but less than half of the width at the level of the primibrachs. The dorsal cup is low truncate bowl-shaped, with a shallow basal concavity. The IBB are almost entirely concealed by the stem. The arrangement of



FIGS. 9–14. Cross sections of dorsal cups of species of *Plaxocrinus*. *9a*, Median section of the dorsal cup of *Plaxocrinus crassidiscus* (Miller and Gurley) through the pB and aR, showing left half of the cup, portion beyond the plane of the section shaded; *9b*, similar section through the lpR and raB, both drawings based on the holotype. *10a*, Median section of the dorsal cup of *Plaxocrinus politus*, n. sp., through the pB and aR; *10b*, similar section through the lpR and raB; both drawings based on the holotype. *11a*, Median section of the dorsal cup of *Plaxocrinus virginarius*, n. sp., through the pB and aR; *11b*, similar section through the lpR and raB; both drawings based on the holotype. *12a*, Median section of the dorsal cup of *Plaxocrinus modestus*, n. sp., through the pB and aR, based on the holotype; *12b*, similar section through the lpR and raB, based on the holotype; *12c*, similar section through the pB and aR, based on the paratype; *12d*, similar section through the lpR and raB, based on the paratype. *13a*, Median section of the dorsal cup of *Plaxocrinus praevalens*, n. sp., through the pB, the aR, and IBr_1 of the anterior ray; *13b*, similar section through the lpR and raB; both drawings based on the holotype. *14a*, Median section of the dorsal cup of *Plaxocrinus orthodoxus*, n. sp., through the pB and aR; *14b*, similar section through the lpR and raB; both drawings based on the holotype.

the BB and RR are those typical for the genus. The transverse convexity in the RR is sufficient to produce a shallow groove at the position of the interradial sutures and there is a very abrupt curvature near the outer margin of the facet that produces an



FIGS. 15 AND 16. Drawings of radial plates and arms of species of *Plaxocrinus*. *15a*, Cross section of the aR of the holotype of *Plaxocrinus praevalens*, n. sp., shaded area being portion of plate beyond the plane of the section, arranged with proximal tip of plate directly below midpoint of outer marginal ridge of facet and indicating facetal angle (*ola*, outer ligament area); *15b*, similar section of the aR of the holotype of *Plaxocrinus modestus*, n. sp.; *15c*, similar section of the aR of the holotype of *Plaxocrinus politus*, n. sp.; *15d*, similar section of the aR of the paratype of *Plaxocrinus modestus*, n. sp.; *15e*, similar section of the aR of the holotype of *Plaxocrinus orthodoxus*, n. sp.; *15f*, similar section of the aR of the holotype of *Plaxocrinus virginarius*, n. sp.; *15g*, similar section of the holotype of *Plaxocrinus crassidiscus* (Miller and Gurley); *15h*, diagram of convexity indices of RR as indicated in preceding figures. *16a*, Drawing of the arms of *Plaxocrinus politus*, n. sp., and showing the arrangement of plates in the anal interradius; *16b*, side view of axillary primibrach of the left posterior ray of this species; *16c*, side view of primibrach and lowest secundibrach of right anterior ray.

arcuate flattened area in this region. A low outer marginal ridge is seen at the edge of the facets on two RR but because of the presence of the IBr in position, no additional observation of the facets is possible. The RA is a narrow plate of subtriangular outline that rests on the upper right edge of the pB, touching both

of the posterior RR, but failing to reach the rpB. The anal x plate, which is pointed below, rests in the notch between the lpR and RA and barely touches the pB. Only the proximal tip of the elongate rt reaches below the upper angle of the rpR.

The IBr_1 are massive axillary segments, the lower part forming an overhang above the summit of the RR and the upper part projecting in the form of a rounded spine (see Fig. 16); the spines are broken off on each of the IBr of the holotype, and accordingly, their original length is not known. The first three to five IIBr in each ray are quadrangular, slightly trapezoidal segments, about half as wide as the IBr. In the two branches of the anterior ray, the $IIBr_6$ is an axillary plate, but other rays show isotomous division on the $IIBr_4$ in one of the primary branches and on the $IIBr_6$ in the other. There are 6 to 8 IIIBr in each branch near the top of the crown (see Fig. 16). The basal part of two sac spines are in place above the arms; these project laterally in the normal fashion of hydreionocrinid genera. Judging by the very closely clustered arrangement of the arms, the anal sac must be extremely slender and tube-like. The surface of the dorsal cup and arms is entirely smooth.

Measurements of the holotype specimen, together with those of the types of *P. crassidiscus* and four new species, are given in the following tabulation.

Measurements, in millimeters, of species of Plazocrinus, based on type specimens

	P. CRASSIDISCUS	P. POLITUS	P. MODESTUS (HOLOTYPE)	P. MODESTUS (PARATYPE)	P. PRAEVALENS	P. VIRGINARIUS	P. ORTHODOXUS
Height of dorsal cup	4.4	2.0	7.5	6.0	11.6	5.8	4.0
Greatest width of cup	17.0	10[a]	34.2	26.3	33.5	18.6	24.0
Ratio of height to width of cup	.26	.20	.22	.24	.36	.31	.17
Height of basal concavity	0.9	0.6[a]	1.7	2.4	2.3	1.3	0.5
Diameter of stem impression	3.0	1.5	5.0	4.0	5.8	3.5	3.9
Length of basal plate (raB)	4.0	2.4	9.1	7.8	13.0	5.3	5.8
Width of basal plate (raB)	4.5	2.5	9.6	7.2	11.2	5.2	6.2
Length of radial plate (aR)	5.4	3.4	8.3	8.9	10.0	6.0	6.2
Width of radial plate (aR)	10.4	6.0	20.8	14.8	22.0	11.2	14.8
Length of transverse ridge (aR)	8.0	5.0[a]	16.4	12.0	16.0	8.6	10.2
Angle of facet	65°	?	70°	63°	80°	80°	55°

[a] Approximate.

Remarks.—The dorsal cup of *P. politus* is rather closely similar in form to that of the genotype species, *P. crassidiscus*, but it is only about one-half as large, proportionally a little lower, the notches at the summit of the RR are less definite, and the BB a little less noticeably convex. Differences in the contour of the cup, and especially that of the RR, distinguish this form from any of the Brownville species here described.

Occurrence.—Middle upper part of the Nelagony formation, (about 35 feet below the Wildhorse limestone member), Virgil series, Pennsylvanian (Upper Carboniferous); Loc. 6066, northwest quarter sec. 21, T. 22 N., R. 10 E., Oklahoma. 100 yards north of the Skiatook-Hominy road, about 15 miles west of Skiatook. Collected by Arthur L. Bowsher.

Types.—Holotype, Kansas Univ., no. 60663.

PLAXOCRINUS MODESTUS Moore, n. sp.

Plate VIII, figures 3a–d, 4a–d; text figures 12a–d, 15 b, d

Description of this species is based on two large dorsal cups which differ from one another slightly but appear to correspond in all essential characters. In addition, a large number of dissociated plates appear to belong to this species. The dorsal cups are low and broad, the height being about one-fourth of the maximum width, and the base is gently concave (Figs. 12a–d). The outline of the cup in ventral or dorsal view appears distinctly angular and straight-sided, but well defined notches located at the summit of the interradial suture and the curved indentation of the posterior interradius interfere with an otherwise perfectly regular pentagonal form.

The plates of the IBB circlet lie horizontal, and form a regular pentagon that is about twice as wide as the diameter of the gently concave stem impression. The proximal parts of the BB flare gently downward and the distal parts upward, a little less than one-half of each plate being visible in side view of the cup; the pB and rpB are slightly larger than the other three plates of this circlet.

The proximal parts of the RR are tangent to the basal plane, or nearly so, but most of their surface has a gentle upward slope;

an arcuate area near the margin of the facets has a nearly vertical position. The sutures between the RR lie in well marked furrows, and there is a rather prominent notch at the summit of the interradial sutures. The facets are narrower than the greatest width of the RR, the transverse ridge of each plate being set well outward from the summit of the interradial sutures. The extension of the outer surface of the RR around the ends of the transverse ridges and into the notch between them does not reach much beyond the depth of this notch, in no case amounting to more than one-third of the distance between the outer and inner extremities of the facets; the lateral ridges of the facets are well separated to the inner border of the facet area, however, and the adsutural slopes form a flat-bottomed depression between them. The outer ligament area is short, almost imperceptibly depressed, except in the area of the ligament pit, and it is bounded by a low outer marginal ridge; the plane of the area is subvertical or sloping very steeply outward. The sharp-crested transverse ridge is accentuated by the angle between the outer and inner ligament areas; the inner side carries moderately long denticles between the extremities of the ridge and the edge of the central dorsal pit. The inner ligament area is characterized by a moderately deep, subtriangular hollow in the position of the central pit, that is confluent with the intermuscular furrow, and also by the broad gently concave muscle areas that are not sharply separated from the oblique furrows; there is a broad but rather deep intermuscular notch, and the lateral ridges are well marked. As shown in figs. 15b, d, the angle of the facet (see Moore, 1939, p. 215), which ranges from about 63 to 70 degrees, aids in distinguishing the RR of this species from those of others somewhat closely related.

The posterior interradius is moderately narrow and stongly depressed. In both of the types the largest of the anal plates is x, which rests on the truncated tip of the pB. The RA fails to touch the rpB, and in the paratype it is reduced to a very small plate located just below and to the right of anal x. The rt plate occurs just above RA.

The surface of this crinoid is smooth.

Measurements of *P. modestus* are tabulated with those *P. politus* and other species on page 226.

Remarks.—The species here described closely resembles the genotype species, *P. crassidiscus* Miller and Gurley, in general form and proportions, but the Brownville form is much larger, the notches between the RR are sharper, the posterior interradius is much more depressed, and the outline of the cup in dorsal and ventral view distinctly more angular. *P. modestus* is distinguished from *P. orthodoxus* chiefly by difference in the angle of the facets and the convexity of the RR plates.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous). The holotype was collected at loc. 4582, near the stockyards at Strohm, Okla.; the paratype is from loc. 5933, railroad cut six miles west of Strohm; both specimens collected by Paul McGuire.

Types.—Holotype, Paul McGuire collection, no. 45822; paratype, no. 59331. The holotype, which is the larger of the two specimens, is not quite so well preserved as the paratype, but it is chosen as holotype because, as judged by comparison with dissociated plates selected from the Brownville limestone, it is the more representative specimen. Plastotypes, Kansas Univ., nos. 45822, 59331.

PLAXOCRINUS PRAEVALENS Moore, n. sp.

Plate VIII, figures 6a–e; text figures 13a, b, 15a

Dorsal cup proportionally high for the genus, and unusually large; in the holotype specimen the height slightly exceeds one-third of the greatest width of the cup.

The IBB circlet is a flat horizontal pentagon, as in *P. modestus*, but it is rather more sharply differentiated from the circlet of BB because of the bulbous nature and the more strongly downflaring attitude of the proximal parts of these plates (Figs. 13a,b). The BB have a distinct transverse as well as longitudinal convexity, and accordingly, all of the bordering sutures are in furrows.

The RR are like those of *P. modestus*, except for somewhat greater convexity and for the greater facetal angle (see fig. 15a), which in this species measures about 80 degrees. The broad

inner ligament area of the facet contains well marked oblique furrows and there is a distinct central pit that is confluent with the intermuscular furrow; the broad triangular muscle areas are gently concave and are smooth except for growth lines that lie parallel to the lateral ridges.

The posterior interradius is strongly indented. An elongate RA lies in normal position, abutting the rpB and along the upper right side of the pB. The anal x plate, equal to the RA in size, rests on the truncated distal tip of the pB, and about two-thirds of its length reaches below the summit of the RR. It is followed above by a tube plate. The proximal one-third of the rt plate is included in the dorsal cup and two additional plates are in position above it.

Two large IBr, slightly displaced but essentially in position, are associated with the holotype specimen. They are very robust spine-bearing plates that correspond in size and general form to very numerous crinoid spines that are found dissociated in the Brownville limestone of northern Oklahoma. The proximal articular area is quadrate, slightly trapezoidal in outline, and its markings correspond essentially to those of the radial facets. On the upper surface are two sub-triangular facets for articulation with two IIBr. A rather distinct bulbous expansion occurs on the under side of the plate and the distal part is produced in a long, gently up-curving spine. The tips of the spines in the holotype specimen are broken off, but it is clear that the original length of these plates was not less than 30 mm. Some dissociated spines, that may, however, belong to *P. modestus*, have a length up to 40 mm. Other parts of the arms and the anal sac are not known. Large anal sac spines, like those belonging to various hydreionocrinid genera, are common in the Brownville limestone and some of them probably represent this species.

The surface of the dorsal cup and the primibrachs is smooth.

Two proximal segments of the stem are attached to the dorsal cup in the holotype specimen. Each segment is round, about 0.8 mm. in length, and the outer surface is straight and smooth. The articular surface is marked by about 40 short, even crenellae, about 0.8 mm. long, and at the center there is a small pentestel-

late lumen, 0.6 mm. in diameter. The area surrounding the lumen is smooth and not depressed.

Measurements of *P. praevalens* are tabulated on page 226 with those of other species of the genus.

Remarks.—The distinguishing features of *P. praevalens* are the relatively high form and large size of the cup, the rather strongly bulbous appearance of the plates, and the large angle of the radial facets. The form of the primibrach spines gives a distinguishing character, as compared with such species as *P. mooresi* (Whitfield), from beds of Des Moines age in Ohio, but the significance of variations in the types of spine plates that are found in the Brownville limestone cannot be determined until such plates are found associated with dorsal cups of other species, as well as that of *P. praevalens.* The possibility that the crinoid described as *P. virginarius* conceivably represents an immature example of *P. praevalens* was carefully considered and rejected. The relatively large height of the cups in these two species and the large facetal angles are points in common, but otherwise there is little similarity, and it does not seem probable that the nearly vertical-sided *P. virginarius* could well be modified into the more flaring form of the cup in *P. praevalens.* Also, the outer ligament area of the facet in *P. virginarius* is proportionally much longer and more distinct than in the other species.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4604, railroad cut five miles west of Strohm, Osage County, Oklahoma. Collected by Paul McGuire.

Types.—Holotype, Paul McGuire collection, no. 460414. Plastotype, Kansas Univ. no. 460414..

PLAXOCRINUS VIRGINARIUS Moore, n. sp.

Plate VIII, figures 2a–e; text figures 11a, b, 15f

Dorsal cup nearly vertical-sided, broadly truncate below, height about one-third of greatest width. There is a very slight basal concavity that is formed partly by the gentle downflaring attitude of the proximal parts of the BB and partly by the slight

concavity of the stem impression (Figs. 11a,b). The IBB circlet is a horizontal pentagon, mostly covered by the stem impression. The BB are very gently convex plates that lie in a nearly horizontal position, but the distal parts curve upward so that they are distinctly visible in side view of the cup.

The RR are rather strongly convex plates; along the interradial sutures there is a shallow furrow and at the top a distinct but shallow notch is found. The outer ligament area of the facet is moderately long and is differentiated sharply on the external side by the outer marginal ridge; this area is not depressed, except in the part occupied by the ligament pit. The transverse ridge is narrow and sharp, bounded on the inner side by well marked denticles, except in the central portion where the subtriangular pit appears; oblique furrows, lateral ridges and intermuscular notch strong; triangular muscle areas smooth; facetal angle 80 degrees.

The posterior interradius is only very slightly depressed. A large RA touches the rpB and is followed above by the relatively small anal x and rt plates, the former resting on the truncated tip of the pB. The nature of the arms and anal sac are not known. The surface is smooth.

Measurements of *P. virginarius* are given with those of other species of the genus on page 226.

Remarks.—The size, gently rounded outline, moderately convex BB, and strongly convex RR of *P. virginarius* correspond generally to those of *P. crassidiscus*, but this Brownville crinoid is distinctly higher and comparison of the two types indicates difference in the appearance of the RR. Also, the facet angle of *P. crassidiscus* is less than that of *P. virginarius*. Rather numerous dissociated plates that appear to belong to this species, especially RR, are separable from those that are tentatively identified as belonging to others of the species recognized. This indicates that although only one complete dorsal cup has been found, the species is not uncommon.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4582, near tank at Strohm, Osage County, Oklahoma, Collected by Paul McGuire.

Type.—Holotype, Paul McGuire collection, no. 45821. Plastotype, Kansas Univ. no. 45821.

PLAXOCRINUS ORTHODOXUS Moore, n. sp.

Plate VIII, figures 1a–c; text figures 14a, b, 15e

Dorsal cup broad and very low, the height measuring only about one-sixth of the greatest width; base very gently concave; IBB circlet pentagonal, horizontal, mostly covered by the concave stem impression, which is bordered by a slight rim; the impression contains 33 crenellae, about 0.9 mm. long, and in the center is a pentestellate lumen, 0.6 mm. in diameter. Proximal parts of the BB flare slightly downward, but most of their length is tangent or nearly parallel to the basal plane of the cup; the distal extremities slope upward so that they are visible in side view of the cup.

The convexity of the RR, both longitudinally and transversely, is low, but there is an abrupt curvature at the outer margin of the facets; the interradial sutures lie in shallow furrows that are best defined near the summit of these plates, where very well marked but shallow notches appear. The outer ligament area of the facet is subvertical in position; except for the ligament pit it is only slightly depressed and is very short. The markings of the inner ligament area are similar to those of *P. modestus*, but the angle of the facet is lower, measuring only 55° in the holotype and as little as 51° in dissociated RR that probably belong to this species.

The posterior interradius is slightly depressed and smoothly concave. The RA is in normal position, touching the rpB; the anal x and rt plates are about as large as the RA and are also normal in position; a small additional tube plate occurs above anal x. Arms and anal sac unknown. Surface smooth. All of the sutures are slightly impressed.

Measurements of *P. orthodoxus* are given with other species of the genus on page 226.

Remarks.—The very low form of the dorsal cup and its relatively smooth contour readily distinguish *P. orthodoxus* from associated representatives of *Plaxocrinus* in the Brownville limestone. The low convexity and small facetal angle of the radial plates also distinguish this species. Several undescribed crinoids

from the Missouri series of Missouri and Kansas approach this species somewhat closely, but they appear nevertheless to be distinct.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4604, railroad cut five miles west of Strohm, Osage County, Oklahoma. Collected by Paul McGuire.

Type.—Holotype, Paul McGuire collection no. 46049. Plastotype, Kansas Univ. no. 46049.

Genus PERIMESTOCRINUS Moore and Plummer, 1938

Perimestocrinus MOORE AND PLUMMER, *1938*, Denison Univ. Bull., Jour. Sci. Labs., vol. 32, (*1937*), p. 281.

The structure of the dorsal cup in this genus is essentially the same as in *Plaxocrinus*, but the height is proportionally greater, the contour of the cup somewhat more even, and the IBB circlet is much more definitely and sharply impressed in the somewhat narrowed basal concavity. The fact that a few dorsal cups show characters that appear transitional between the normal forms of the cups in these two genera is by no means thought to make differentiation of them invalid, for a large majority of specimens can be assigned to one or the other without much difficulty. It seems probable, however, from similarities of the cup and from what is known of the nature of the arms, that the two genera are closely related.

Remarks.—Besides the genotype and one other species assigned to this genus from the Missouri series at Kansas City, two lower Pennsylvanian species have been described (Moore and Plummer, 1938, pp. 281–285) from Morrow beds in Oklahoma and Arkansas. Three species from Des Moines and Missouri beds of Texas have been studied and described in manuscript (Moore and Plummer, 1939). Restudy of the holotype of Weller's *Delocrinus excavatus* (Weller, 1909) from the Lower Permian of western Texas, shows that this cup belongs to a hydreionocrinid having characters of *Perimestocrinus*, and accordingly, this species has been transferred from *Delocrinus*. The species from upper most Pennsylvanian deposits of northern Oklahoma, de-

scribed in this paper, shows departure from normal characters of the genus in the low form of the cup.

Occurrence.—Morrow to Virgil series, Pennsylvania (Upper Carboniferous), and Lower Permian, central United States.

Genotype.—Hydreionocrinus nodulifer Miller and Gurley.

PERIMESTOCRINUS SUBTILIS Moore, n. sp.

Plate VII, figures 4a–c; text figures 17a–c

Dorsal cup low, truncate bowl-shaped, with rounded pentagonal outline in dorsal or ventral view; general contour of the cup even, except for slightly impressed sutures. A moderately small steep-walled basal concavity involves the IBB circlet and the proximal parts of the BB. The IBB form a pentagon that is mostly covered by the shallow concave stem impression. The BB join the IBB with sharp angulation, for at first they slope strongly downward, but they curve outward so as to be tangent to the basal plane of the cup at about their mid-length. (Figs. 17a,b), and the distal parts are visible in side view of the cup.

The RR are strongly convex longitudinally, but there is not enough lateral curvature to produce distinct furrows along the interradial sutures; an arcuate area in the distal part of the plates is abruptly bent from that of the remainder and forms with the outer ligament area a nearly flat surface that is vertical or slopes slightly inward. The articular facets are slightly narrower than the greatest width of the RR, notches appearing at the summit of the interradial sutures. The angle between a horizontal plane and the outward sloping inner area of the facets is about 36 degrees. The chief features of this area are the strongly developed lateral ridges and the moderately deep oblique furrows.

Only one anal plate, the RA, is preserved in the holotype specimen, but notches above it indicate the positions of the anal x and rt plates. The RA does not touch the rpB. The tip of the pB is truncated for contact with anal x, but the short length of this suture and its position close to the summit of the RR indicates either that the anal x is very small or that most of it is above the edge of the dorsal cup. The notch between the RA and the upper angle of the rpR is extremely small, showing that the rt is

practically excluded from the cup. The posterior interradius is not depressed. The surface of the cup is smooth.

Measurements of the dorsal cup of *P. subtilis*, in millimeters, are as follows: Height of dorsal cup, 3.0; greatest width of cup, 14.3 mm.; ratio of height to width, .21; height of basal concavity 1.3; diameter of stem impression 2.0; width of IBB circlet, 3.2; length of raB, 4.3; width of raB, 3.7; length of aR, 4.3; width of aR, 8.3; length of transverse ridge of aR, 6.4; angle of facet, 75°.

Remarks.—The height of the dorsal cup in *P. subtilis* is less than one-third that of the greatest width, and this character, without notice of others, serves readily to distinguish this species from *P. nodulifer* and other described species. The general proportions and outline of the cup suggest comparison with *Plaxocrinus crassidiscus*, but from this, and other species of that

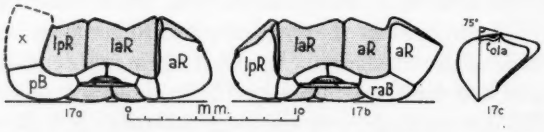


FIG. 17. Drawings of the dorsal cup and radial plate of *Perimestocrinus subtilis*, n. sp., based on the holotype. *17a*, Median section of the dorsal cup through the pB and aR, shaded area representing portion of the cup beyond the plane of the section; *17b*, similar section through the lpR and raB; *17c*, section of the aR arranged with proximal tip of the plate below the midpoint of the outer marginal ridge of the facet and showing facetal angle (*ola*, outer ligament area).

genus, the present species is readily differentiated by the sharply depressed central concavity.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4604, railroad cut five miles west of Strohm, Osage County, Oklahoma. Collected by Paul McGuire.

Type.—Holotype, Paul McGuire collection no. 460411. Plastotype, Kansas Univ. no. 460411.

Genus UTHAROCRINUS Moore and Plummer, 1938

Utharocrinus MOORE AND PLUMMER, *1938*, Denison Univ. Bull., Jour. Sci. Labs., vol. 32 (*1937*), p. 285.

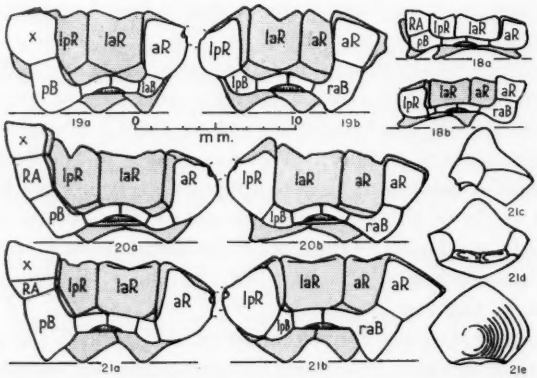
This genus was established to contain *Delocrinus pentanodus* Mather, from Morrow beds in northeastern Oklahoma, because

study of this crinoid shows plainly that it cannot belong to *Delocrinus*, and it did not appear assignable to any other described genus. In discussion of *Utharocrinus*, mention was made (Moore and Plummer, 1938, p. 287) of new species from upper Pennsylvanian horizons that showed certain resemblances to *U. pentanodus*. Three of these species are described here and although they differ rather obviously from the genotype of *Utharocrinus* in some characters, it seems best to place them in this genus.

The form of the dorsal cup in *Utharocrinus* is that of a low truncate bowl that is set on five short legs consisting of spinous projections of the BB; the base of the cup is slightly concave and the sides slope upward steeply. The five plates of the IBB circlet form a regular pentagon that is approximately horizontal. The proximal parts of the BB flare downward, the middle parts are produced in a spinelike bulge, and the distal parts slope upward steeply. Accordingly, the BB, but not the IBB, are visible in side view of the cup.

The RR are strongly convex longitudinally, and in the genotype species, their proximal portions lie approximately parallel to the basal plane of the cup. The articular facets slope outward, slightly in *U. pentanodus* (about 13°), more steeply in the new species here described (23° to 33°) (see Figs. 18a,b). A single anal plate of asymmetrical form occurs in the holotype of *U. pentanodus*, and because of its position, this plate is identified with some confidence as the RA. The distal edge of this plate does not quite reach the summit of the posterior RR, and the occurrence of two slight depressions on this suture face may be inferred to mean that anal x and rt barely enter the dorsal cup. Three anal plates are definitely recognized in the cups of each of the three new species here described, but in one of them the two upper plates are practically excluded from the cup. Characters of the posterior interradius are well known to show evolutionary modification and a certain amount of variability in different poteriocrinid genera, and even within the limits of a single species. It is believed that the generic diagnosis of *Utharocrinus* should indicate existence of three anal plates in the dorsal cup

as a normal occurrence, but at the same time it is proper to stress the tendency toward migration of anal x and rt above the summit of the RR, so that in some cases one or both of these plates are virtually or actually excluded from the dorsal cup. The stem impression in cups of *Utharocrinus* is round, the character of the arms and anal sac is not known.



FIGS. 18–21. Drawings of dorsal cups and a basal plate of species of *Utharocrinus*. *18a*, Median section of the dorsal cup of *Utharocrinus pentanodus* (Mather), the genotype species, through the pB and aR, the shaded area representing parts of the cup beyond the plane of the section; *18b*, similar section through the lpR and raB; both drawings based on the holotype. *19a*, Median section of the dorsal cup of *Utharocrinus topekensis*, n. sp., through the pB and aR; *19b*, similar section through the lpR and raB; both drawings based on the holotype. *20a*, Median section of the dorsal cup of *Utharocrinus oreadensis*, n. sp., through the pB and aR; *20b*, similar section through the lpR and raR; both drawings based on the holotype. *21a*, Median section of the dorsal cup of *Utharocrinus quinquacutus*, n. sp., through the pB and aR; *21b*, similar section through the lpR and raB; both drawings based on the holotype; *21c*, side view of a large dissociated basal plate from the Brownville limestone (loc. 5932), assigned to *U. quinquacutus; 21d*, proximal view of same; *21e*, exterior surface of same.

Remarks.—Comparative study of dorsal cups assigned to this genus rather clearly shows that in the general upward migration of plates belonging to the anal series, the RA is not resorbed, while anal x retains its position, but it is shifted gradually upward replacing anal x. This same tendency is witnessed in various

other hydreionocrinid genera, but on the other hand, there are some crinoids in which the RA appears gradually to become smaller, while the anal x and rt plates are identifiable in their normal position. Accordingly, evidence seems to support the conclusion that both types of evolutionary change operate in different cases to reduce the number of anal plates in the dorsal cup, one with and the other without resorption of the RA.

The chief distinguishing feature of *Utharocrinus* is the more or less strongly developed spines or nodes on the BB. Only one other genus, *Dinocrinus* Wanner (1924, p. 248) is noted that is especially characterized by a similar peculiarity. The form of the dorsal cup in *Dinocrinus* is quite different from that of *Utharocrinus*, the RR being much reduced and the BB greatly enlarged; also, the IBB are reported to be visible in side view of the cup.

Occurrence.—Morrow to Virgil series, Pennsylvanian (Upper Carboniferous) central United States.

Genotype.—*Delocrinus pentanodus* Mather.

UTHAROCRINUS QUINQUACUTUS Moore, n. sp.

Plate VII, figures 1a–c; text figures 21a–e

The type specimen of this interesting little crinoid is a nearly perfect, dorsal cup that attracts attention first because of the spinous projections on the BB. The outline of the cup in dorsal or ventral view is markedly angular rather than rounded, and the straight edges of the RR form a nearly regular pentagon. The sides of the cup flare outward to the borders of the facets without approaching a vertical position; thus the widest part of the cup is in the plane of the summit of the RR. The relatively narrow basal concavity is bordered by the abrupt proximal walls of the spines, but in the gaps located along the interbasal sutures, the sides of the depression are inconspicuous.

The IBB form a regular pentagon that lies in a subhorizontal position at the top of the basal concavity, and it is largely covered by the round stem impression. The BB are subequal in size, their chief feature being the projection nearly straight downward of a spine that is located much nearer to the proximal than to the

distal margin; on some of the plates this spine is on the midline of the plate longitudinally, but in others it is slightly to the right or left of this line.

The RR are very gently convex longitudinally and transversely, and the rather even outward and upward flare of their surface is noteworthy. Very shallow furrows occur along the sutures both at the proximal and lateral edges of each plate; also, there is a small sharp dimple at each angle where three plates meet. Markings on the articular facets are exceptionally well preserved in the type specimen and call for special notice. The outer ligament area has a length that is a little less than one-fourth of its width; the angle between its plane and the vertical plane passing through the transverse ridge is about 15°, and the direction of inclination is downward and inward from the transverse ridge; the angle between the outer and inner ligament area is about 147°. The outer marginal ridge is low but distinct; the outer ligament furrow, adjoining it, is a smooth-bottomed gently concave area that occupies a little more than half of the outer ligament area; the outer ligament ridge is strong; the ligament pit, which lies between this ridge and the transverse ridge, is deep, but the ligament pit furrow is almost a plane surface. The transverse ridge is sharp-crested, lacks denticles, but on each side of the ligament pit the crest bears very narrow slits that are about as long as the ligament pit. The inner ligament area shows a deep central dorsal pit of triangular form; strongly marked oblique furrows that are most sharply defined adjacent to the lateral angles and near the center of the area; broad, nearly smooth subtriangular muscle areas that bear growth lines parallel to the trend of the lateral ridges, which are rather strongly elevated; a shallow intermuscular furrow that is bordered by a slightly raised rim; a moderately well defined intermuscular notch; the adsutural slopes have a uniform inclination so that angular grooves are formed along the sutures between facets; a trefoil-like prominence lies between the central dorsal pit and the end of the intermuscular furrow. In varying development, different ones of these features are seen on the facets of various poteriocrinid cups, but in few are all of them seen and in still fewer are they so clearly discernible.

The posterior interradius is relatively narrow and moderately depressed. There are three anal plates in the cup, although one of them, the rt, is missing in the holotype specimen. The RA is a small plate of triangular outline that lies obliquely at the right above the pB and reaches more than half of its length above the summit of the RR. The rt enters the dorsal cup only slightly, and in the holotype, this plate is not in contact with the RA below it. The surface of the dorsal cup is ornamented by small round granules, each about 0.07 mm. in diameter at the base and spaced one to three or four times this distance apart. The granules are somewhat too fine to be seen readily with the unaided eye, but are clearly evident under a lens.

Measurements of *U. quinquacutus*, with those of other species of the genus, are given in the following tabulation:

Measurements of species of Utharocrinus, in millimeters, based on type specimens

	U. PENTANODUS	U. OREADENSIS	U. TOPEKENSIS	U. QUINQUACUTUS
Height of dorsal cup	2.2	4.6	5.5	4.2
Greatest width of cup	8.8	14.2	12.4	15.2
Ratio of height to width of cup	.25	.32	.44	.28
Height of basal concavity	1.2	1.7	1.7	2.4
Height of basal concavity exclusive of projecting spines	0.5	0.9	0.8	1.1
Diameter of stem impression	1.9	2.4	2.0	2.2
Width of IBB circlet	3.0	3.7	3.7	3.6
Length of basal plate (raB)[1]	4.0	5.1	5.3	5.7
Width of basal plate (raB)	2.5	4.5	4.9	5.2
Length of radial plate (aR)	3.6	4.3	2.8	3.7
Width of radial plate (aR)	5.2	8.0	6.4	8.8
Length of transverse ridge	4.2	5.6	5.0	7.5
Angle of facet[2]	48°	72°	82°	56°

[1] Measured along surface, including sides of spinous bulge.

[2] Measured between plane of inner ligament area and line from midpoint of outer marginal ridge to proximal tip of radial (see Moore, 1939, p. 218).

Remarks.—The stronger development of the basal concavity, the longer and more pointed nature of the spinous projections of the BB, and their location closer to the proximal than the distal margins, distinguish *U. quinquacutus* from *U. oreadensis.* Also, the posterior interradius of the latter species is less depressed

and the granulose ornamentation is finer than in the species from the Brownville limestone. The cup of *U. topekensis* is narrower and more steep-sided and decoration is lacking in this species.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4604, railroad cut five miles west of Strohm, Osage County, Oklahoma. Collected by Paul McGuire.

Types.—Holotype, McGuire collection, no. 46048. Plastotype, Kansas Univ. no. 46048.

UTHAROCRINUS OREADENSIS Moore, n. sp.

Plate VII, figures 2a–c; text figures 20a,b

The dorsal cup of this species closely resembles that of *U. quinquacutus*, but the spinous projections of the BB are lower and farther apart; also, the outline of the cup in dorsal or ventral view is somewhat less sharply angular. The height of the cup is almost exactly one-third of the greatest width (measured from the basal plane to the height of the transverse ridge). The basal concavity, measured from the plane defined by the tips of the spines on the BB, is some less than in *U. quinquacutus*, but ignoring these spines, it is about the same.

Most of the IBB pentagon is occupied by the concave stem impression. This bears 22 strong crenellae reaching halfway to the slightly pentalobate lumen, 0.3 mm. in diameter, at the center. The distal parts of the IBB are horizontal, or flare very slightly downward. The BB are subequal plates, all pentagonal except the pB, which is hexagonal. A strong tubercle or short spine, directed somewhat outward as well as downward, is located on each plate of this circlet closer to the distal than the proximal margin.

The RR slope rather evenly outward and upward, the greatest convexity being located near the border of the facets; the transverse curvature is such as to produce shallow furrows in the position of the interradial sutures, and in the notches between the facets at the summit of the RR, the surface curves inward well beyond the ends of the transverse ridges, where it becomes practically confluent with the broad angular notch formed by the

adsutural slopes. Characters of the facets are generally like those described for *U. quinquacutus* but are less well preserved; the outward slope of the inner ligament area (27°) is a little less than in *U. quinquacutus* (33°), but the angle between the planes of the outer and inner ligament areas is greater (152° compared with 147°).

The structure of the posterior interradius, which is narrow and not depressed, is very interesting in its close similarity to that of *U. pentanodus*. A large plate, which is clearly the RA, rests against the upper right side of the pB, but is not in contact with the rpB; it occupies the space between the posterior RR to a height above that of their transverse ridges but not quite to the elevated top of projecting sides of the facets. A part of anal x that is barely 0.1 mm. in length can be said to be in the cup and the base of rt is exactly on the line reached by the highest part of the front of the rpR, although on the inside of the cup these plates reach, respectively, 1.8 and 1.3 mm. below the tops of the radials adjoining them. All three anal plates are thus to be regarded as included in the cup.

The surface of the plates in this crinoid are decorated by minute granules that are somewhat finer and distinctly more closely spaced than in *U. quinquacutus*; they are visible only with aid of a good lens.

Measurements of this species are given with those of others belonging to this genus on page 241.

Remarks.—The chief distinguishing features of this species are its fine granulose ornamentation, the low spines on the BB, and their somewhat laterally directed position on these plates. Only the holotype specimen is available, and therefore the possibility of variation in the structure of the posterior interradius and its nature cannot be determined. The arrangement of the BB spines is more like that of *U. pentanodus* than in the other species described, although the spines of the Morrow species are much more pointed; *U. oreadensis* is a much larger, relatively higher cup, with more steeply outward facing facets.

Occurrence.—Plattsmouth limestone member of the Oread formation, Shawnee group, Virgil series, Pennsylvanian (Upper Car-

boniferous); loc. 6022. Quarry near depot at Lecompton, Kansas. Collected by Arthur Bridwell.

Type.—Holotype, Kansas Univ., no. 60221.

UTHAROCRINUS TOPEKENSIS Moore, n. sp.

Plate VII, figures 3a–c; text figures 19a,b

Dorsal cup essentially like that of the other two new species of *Utharocrinus* described here. Spines of the BB well defined, located at about the mid-length of these plates; the tips of all are broken off, making possible the supposition that the original length may be 0.5 to 1.0 mm. greater than that now observed. The RR are characterized especially by differentiation of an arcuate area near the distal margin; this consists of four or five low nodes arranged in a curving row on each plate and forming a discontinuous ridge that is accented at termini in the interfacet notches. The most noteworthy features of the facets are the strongly marked oblique furrows and the rounded lateral ridges of the inner ligament areas; the angle between the outer and the inner ligament areas is about 127°.

The posterior interradius is not depressed and does not interrupt the rounded contour of the cup. Three anal plates are in normal position, the RA resting against the rpB, anal x on the truncated tip of pB, and the rt directly above RA. All are well within the cup. The surface of the plates is without decoration except the spinous projections and tubercles that have been noted. The sutures are all very distinct though not impressed. A minute pit is located at each angle where three plates meet.

Measurements of this species are given on p. 241.

Remarks.—Most closely similar to this species is *U. quinquacutus*, which has relatively strong basal spines directed downward and only a little outward, as in *U. topekensis*. The dorsal cup of the latter species is narrower and higher than any other yet referred to the genus. The row of nodes on each R and lack of fine granulose ornamentation also serve for identification of *U. topekensis*.

From the standpoint of evolutionary modification of plates belonging to the posterior interradius, the structure seen in *U.*

topekensis is the most primitive. *U. quinquacutus* shows advancement in the migration of RA away from contact with the rpB to a position obliquely above the pB, which is separated from contact with anal x, but x and rt are well within the cup. In *U. pentanodus* and *U. oreadensis*, anal x and rt appear to have retreated almost or entirely out of the cup, although their presence below the summit line of the RR is indicated plainly on the interior side of the cup. The order of these species arranged according to degree of preservation of the anal series in the cup has no correlation with the stratigraphic appearance of the species, for the oldest is *U. pentanodus*, the next *U. oreadensis*, the third *U. topekensis*, and the fourth *U. quinquacutus*.

Occurrence.—Coal Creek limestone member of the Topeka formation, Shawnee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4572, on Crooked Creek just west of north-south highway, 8 miles north of Oskaloosa, Jefferson County, Kansas. Collected by Arthur Bridwell.

Type.—Holotype, Kansas Univ. no. 45721.

Genus GRAPHIOCRINUS De Koninck and Le Hon, 1854

Graphiocrinus De Koninck and Le Hon, *1854*, Acad. Royale Belgique, Mém., vol. 28, no. 3, p. 115. ———, Wachsmuth and Springer, *1879*, Revision of Palaeocrinoidea, pt. 1, p. 121. ———, Springer, *1911*, Harvard Mus. Comp. Zoology, mem., vol. 25, no. 3, p. 144; *1913*, (part), in Zittel-Eastman, Textbook of Palaeontology, p. 225. ———, Wanner, *1916* (part), Paläontologie von Timor, Lief. 6, Teil 11, p. 166; *1924* (part), Mijnwezen nederl. Oost-Indië, Jaarb., Verhandel. 1921, Gedeelte 3, p. 232; *1937* (part), Palaeontographica, Suppl. Bd. 4, Abt. 4, Teil 2, p. 172. ———, Moore and Plummer, *1939*, Univ. Texas, Bull., (in press).

Scaphiocrinus Hall, *1858* (part), Iowa Geol. Survey, vol. 1, pt. 2, p. 549.

Graphyocrinus Kenn. (*Graphiocrinus* De Koninck and Le Hon), *1926*, Tien, Geol. Survey China, Paleont. Sinica, ser. B, vol. 5, fasc. 1, p. 40.

Based on characters of the genotype species, *Graphiocrinus* is distinguished by the tall, slender nature of the crown. It consists of a small, truncate bowl-shaped dorsal cup and ten uniserial arms, isotomous branches being formed on the first primibrach. Although the presence of IBB plates was not observed by De Koninck and Le Hon, these are demonstrated to occur in the small basal concavity; they are very small and are

five in number. Only the BB and RR are visible in side view of the cup. The BB are subequal in size; a small proximal part may be included in the basal concavity, but the basal plane of the cup is tangent to the BB in the proximal half of these plates, most of the distal part being distinctly up-flaring. The articular facets occupy the full width of the RR. A single anal plate occurs below the summit of the RR, slightly separated from contact with the pB in the specimen first described by De Koninck and Le Hon, but in other typical examples this plate rests on the truncated tip of the pB (Springer, 1911). The stem is small and round. The nature of the anal sac in the genotype species is not recorded, but in some other species that appear properly referable to the genus, a slender tubular sac is observed.

Remarks.—At least a dozen poteriocrinid genera have dorsal cups that are structurally similar to the cup of *Graphiocrinus*, with a single anal plate below the summit of the RR and five plates in the IBB circlet. Difference in the structure of the arms serves readily to separate *Graphiocrinus* from *Bursacrinus* Meek and Worthen, *Paraburs acrinus* Wanner, *Delocrinus* Miller and Gurley, *Paragraphiocrinus* Wanner, *Philocrinus* De Koninck, *Aesiocrinus* Miller and Gurley, *Ceratocrinus* Wanner, *Synyphocrinus* Trautschold, and *Spheniscocrinus* Wanner. In the case of *Dinocrinus* Wanner, *Roemerocrinus* Wanner, and *Benthocrinus* Wanner, the structure of the arms is not known, but the form of the dorsal cup of these genera differs markedly from that of *Graphiocrinus*.

Proper generic allocation of dorsal cups among some members of this group may be very difficult and uncertain if knowledge of arms structure is lacking, as noted by Wanner (1924, p. 236; 1937, p. 173). Nevertheless, features of the dorsal cup should be reasonably constant, and in proportion as this is true, identification is facilitated. For example, no undoubted representative of *Aesiocrinus* lacks a well defined pentagonal stem impression, a base that is flatly rounded, or only very slightly concave, and a more or less distinct asymmetry produced by difference in the steepness of the anterior and posterior slopes of the cup; these features and the inward inclination of the articular facets give

definite characteristics that distinguish this genus, even though arms are lacking. It is recognized that in certain cases genera having readily distinguishable features of the crown may have essentially identical dorsal cups, but there is much evidence to show that specific types of dorsal cups are constantly associated with individual genera. One feature that is almost universally recognized as important in generic classification is the presence or absence of a basal concavity of the cup; if the IBB flare upward and are visible in side view of the cup, the genus represented can hardly be the same as one in which the IBB are horizontal or slope downward, and are not visible in side view of the cup. Such distinction is so generally substantiated and well accepted that it is surprising to find associated together such dissimilar dorsal cups, as those which Wanner (1937, pp. 172, 173) calls *Graphiocrinus scrobiculatus* (Wanner) and *Graphiocrinus declivis* Wanner, for in the first named species the IBB are very plainly visible from the side and in the latter they are entirely concealed in the basal concavity. No acceptable evidence has been adduced to show that dorsal cups differing from that of the genotype of *Graphiocrinus*, in which the small IBB are concealed in the basal concavity, should be included in this genus.

Restricting attention to dorsal cups having one anal plate and five IBB that are not visible in side view of the cup, we find the following poteriocrinid genera: *Benthocrinus*, *Parabursacrinus*, *Ceratocrinus*, *Aesiocrinus*, *Delocrinus*, *Spheniscocrinus*, *Graphiocrinus*, and *Paragraphiocrinus*[5]. The first two of these are readily separated from *Graphiocrinus* by the large size of the basal concavity and entirely different form of the cup. *Ceratocrinus* has articular facets that slope steeply outward and are narrower than the greatest width of the RR. *Aesiocrinus* has a pentagonal stem impression and inward sloping facets. A study of several hundred cups of *Delocrinus* belonging to numerous species, emphasizes the importance as a generic feature of the narrow, rela-

[5] To this list *Enerisocrinus* Strimple (1939, p. 13) should possibly be added; this form has a flat base and evenly flaring sides, like *Erisocrinus*, but it has one anal plate in the dorsal cup. Strimple's new genera *Moundocrinus* (op. cit., p. 9) and *Pentadelocrinus* (op. cit., p. 11) are believed to be synonyms of *Aesiocrinus*.

tively deep basal concavity that involves much of the area of the BB; this character is not found in *Graphiocrinus*. A single specimen from the Permian rocks of Timor is at present the only known representative of *Spheniscocrinus;* the form of its cup is much like that of *Graphiocrinus*, although the plates are more bulbous, sutures more impressed, and the large round stem entirely conceals the IBB. The base of the cup of *Paragraphiocrinus*, as represented by the genotype species, *P. exornatus* (Wanner), is flat or very slightly convex, so that in some figures the IBB are indicated as visible in side view of the cup; the IBB are plainly seen in side view of the cup of the one other species that is tentatively referred to this genus, *P. punctatus* Wanner.

In spite of some difficulty, it seems possible to discriminate types of dorsal cups like that of the genotype of *Graphiocrinus*, but this cannot be done if the genus is loosely defined as to shape of the cup and attitude of plates, especially in the IBB and BB circlets. Crinoids in which the IBB are visible in side view of the cup are here excluded from this genus. Also, without reference to arm structure, it seems possible to differentiate dorsal cups of *Graphiocrinus* from those belonging to *Delocrinus* by differences in the nature of the basal concavity.

Crinoids of the type represented by *"Graphiocrinus" carbonarius* Meek and Worthen, and *"G." quinquelobus* Wanner do not belong in *Graphiocrinus;* this is indicated especially by the nature of the facets, and these species are referred to a new genus (Moore and Plummer, 1939).

Occurrence.—Lower part of Lower Carboniferous, Europe and North America, Missouri and Virgil series, Pennsylvanian (Upper Carboniferous) central United States, Permian, Sicily, and Timor.

Genotype.—G. encrinoides De Koninck and Le Hon, Lower Carboniferous, Belgium.

GRAPHIOCRINUS DELICATULUS Moore, n. sp.

Plate IX, figures 6a–c; text figures 22a,b

Dorsal cup bowl-shaped, with a slightly truncate base containing a small pit-like concavity; the height of the cup is two-

fifths that of the greatest width; the sides have an even upward curvature (Figs. 22a,b). The IBB are located in the basal concavity and flare downward from the round stem impression, their distal tips touching or barely failing to touch the basal plane of the cup. Excepting an inconsequential space at the proximal edge of the BB amounting to one-tenth or less of the total length of the plates, the BB curve upward evenly from a position tangent to the basal plane of the cup, and reach half way to the summit; the pB is only a little larger than the other plates of this circlet, its distal edge being truncated for contact with the anal x.

The width of the RR is almost equal to their length, and the convexity of these plates is such as not to interfere with the smooth contours of the cup. The articular facets occupy the full width of the RR, and except for a distinct outward slope of the

FIG. 22. Median cross section of the dorsal cup of *Graphiocrinus delicatulus*, n. sp., based on the holotype specimen, shaded area representing parts of the cup beyond the plane of the sections. *22a*, Section through the pB and aR; *22b*, section through the lpR and raB.

outer ligament area, and a slight outward slope of proximal parts of the lateral ridges on the inner ligament area, the plane of the facets is nearly horizontal. The outer ligament area is short, very slightly depressed, and it contains a small ligament pit; the inner ligament area is distinguished by strong development of the oblique furrows and elevations along the outer part of the lateral ridges and at the edges of the intermuscular notch.

The anal x is hexagonal in outline, although at first glance it appears quadrangular; it is longer than wide and about two-fifths of its length rises above the summit of the RR, curving inward slightly.

The surface of the cup is smooth; the sutures are distinct but not at all impressed.

Measurements of the dorsal cup of the holotype, in millimeters, are as follows: height of cup, 3.1; greatest width of cup, 7.5;

ratio of height to width, 0.41; height of basal concavity, 0.7; width of infrabasal circlet, 1.6; diameter of stem impression, 0.9; length of basal plate (raB), 3.0; width of basal (raB), 3.0; length of radial plate (aR), 2.5; width of radial (aR), 4.5; length of transverse ridge, 3.7; width of body cavity, 3.7; angle of facets 67°.

Remarks.—The dorsal cup of *G. delicatulus* resembles that of *G. encrinoides* De Koninck and Le Hon in its slightly truncated bowl-shaped form and the presence of small basal concavity that is formed almost entirely by the IBB plates. The sides of the cup in *G. delicatulus* are more evenly rounded and the height is proportionately greater. The cup of *G. longicirrifer* (Wachsmuth and Springer), from lower Mississippian beds of Iowa, corresponds almost exactly in size and proportions to this new species, but the Iowa form has straighter sides and a narrower base. Closest correspondence in appearance is found in a comparison of *G. delicatulus* with *G. declivis* Wanner, from Permian rocks of Timor; the shape and proportions of cups in these two species are almost identical, and the nature of the narrow basal concavity, formed almost wholly by the down-flaring IBB plates, is the same; the BB of *G. declivis* appear slightly more bulbous, and the cup is more than twice as large as that of *G. delicatulus*.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 5932, railroad cut, seven miles west of Strohm, Osage County, Oklahoma. Collected by Paul McGuire.

Type.—Holotype, McGuire collection (plastotype, Kansas Univ. no. 45783).

Genus AESIOCRINUS Miller and Gurley, 1890

Phialocrinus Trautschold (not Eichwald), *1879*, Soc. Imperiale Naturalistes Moscou, Nouveaux Mémoires, vol. 14, fasc. 1, p. 24.

Aesiocrinus Miller and Gurley, *1890*, Cincinnati Soc. Nat. Hist., Jour., vol. 13, p. 14; 1890, Indiana Dept. Geol. Nat. Hist., 16th Ann. Rept., p. 337.

The dorsal cup of crinoids belonging in this genus is low, somewhat asymmetrically bowl-shaped, the posterior side sloping less steeply than the anterior side. The flat base is formed by

the five small plates of the IBB circlet, which bears at its center a strongly angular pentagonal stem impression. The proximal part of the BB may also be tangent to the basal plane of the cup, but most of the area of these relatively large plates lies above the basal plane, curving evenly upward to form the sides of the cup.

The RR are distinguished from those of most other poteriocrinid genera by characters of the facets, the inner ligament area being short, nearly plane, and having an unusually small facetal angle; because of this small angle, the plane of the facet slopes toward the interior of the dorsal cup in most species. There is a single, relatively large anal plate that rests squarely against the pB, and it tends to slope outward, rather than to curve inward in the distal region. The arms are rather long, slender, composed of quadrangular, uniserially arranged segments that bear long delicate pinnules; the arms branch typically on the IBr_2 so as to make 10 arms that spread horizontally outward from the cup, but some species with more than 10 arms and two with only 5 arms are included at present in the genus.

A distinctive feature is the long anal sac, formed by four or five columns of rounded or rugose plates, with respiratory slits along suture lines between the columns. The stem is sharply pentagonal in outline.

Remarks.—This genus has long been confused with *Graphiocrinus* (see Springer, 1911, p. 145; 1913, p. 225) and *Phialocrinus* (Keyes, 1894, p. 220; Weller, 1898, p. 420) but it is, almost without question, a readily distinguished and valid genus. Although *Graphiocrinus* has a low bowl-shaped cup with one anal plate and ten uniserial arms, it is probably only very distantly related to *Aesiocrinus*, belonging in an entirely different branch of the poteriocrinids. The stem of *Graphiocrinus* is perfectly round; the more or less marked asymmetry of the dorsal cup that seems to characterize all species of *Aesiocrinus* is not a feature of *Graphiocrinus*; and cups belonging to the former are almost invariably much larger than those belonging to the latter; the anal plate of *Aesiocrinus* is persistently larger in proportion and somewhat differently disposed than in the compared genus, and especially the very strong anal tube of *Aesiocrinus* is foreign to *Graphio-*

crinus. The arms of the two genera are different, those of *Aesiocrinus* being distinctly more rounded in cross section and tending to extend outward subhorizontally, rather than flattened at the sides because of apposed vertical position above the cup. Finally, it is believed that the radial facets are dissimilar; the facets of the genotype species of *Graphiocrinus* are not described and have not been seen by me, but those of other species that seem properly placed in the genus are subhorizontal or slightly outsloping, as in *Delocrinus* and the facetal angle is much larger than in *Aesiocrinus*.

Phialocrinus, as proposed by Trautschold (1879), is an invalid genus, for it is a homonym of *Phialocrinus* Eichwald, 1856. Study of a well preserved specimen of Trautschold's genotype species of *Phialocrinus, P. patens*, shows correspondence in all characters, including indication of a strong anal sac (although this is not mentioned by Trautschold) with *Aesiocrinus*, and there seems to be no doubt as to its belonging to Miller and Gurley's genus. Another of Trautschold's species, *Phialocrinus urna*, is evidently not an *Aesiocrinus*, however.

Occurrence.—Near top of the Lower Carboniferous in Scotland, and apparently distributed throughout the Upper Carboniferous in the central United States, though known definitely only from the Missouri and Virgil series.

Genotype.—*Aesiocrinus magnificus* Miller and Gurley, from the Lane shale, Kansas City group, Missouri series, at Kansas City, Mo.

AESIOCRINUS DILATUS Moore, n. sp.

Plate V, figures 9a–c, 10a,b; text figures 23a–l

The collection of Brownville crinoids contains one incomplete dorsal cup that is clearly identifiable as belonging to *Aesiocrinus*. In addition, there are quite a number of dissociated radial and basal plates, some of which belong to the species that is represented by the dorsal cup and some to other species. The dorsal cup, just mentioned, lacks part of the laB, laR, and raR. The cup is so low and distinctly asymmetrical that, when first examined, the flatness of the form was thought to be due mainly to

deformation of the specimen by compression (Fig. 23a). Closer study has shown that while a small amount of such distortion may have occurred, perhaps, this is not great, for the spaces at the summit of the cup left by the missing laR and raR correspond closely in width to the width of other radials of the cup.

The height of the dorsal cup is approximately one-third that of the greatest width. The base is broadly flattened and there is a very small concavity that involves the central part of the IBB circlet. The posterior side of the cup is slightly longer than the

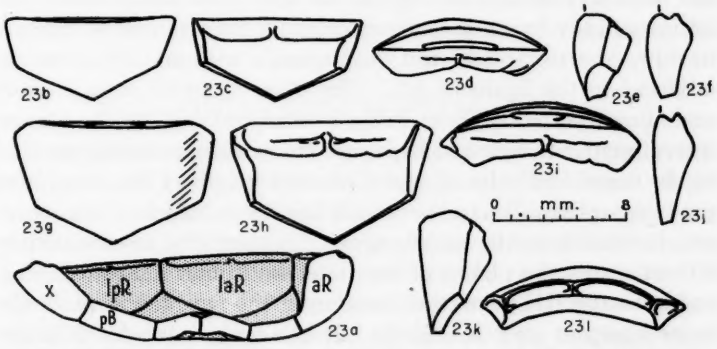


FIG. 23. Median cross section of the dorsal cup of *Aesiocrinus dilatus*, n. sp., based on the holotype, and drawings of radial plates belonging to this species. *23a*, Section of cup through the pB and aR, shaded area representing parts of cup beyond the plane of the section; *23b–f*, drawings of the aR of the holotype, showing exterior view, interior view, top view, side view, and median section, respectively; *23g–l*, drawings of a dissociated radial from the Brownville limestone (loc. 4604) that is assigned to this species, showing exterior view, interior view, top view, median section, side view, and bottom view, respectively.

anterior side, and its upward curvature is much more gentle than that of the anterior side (Fig. 23a). The IBB form a slightly stellate pentagon; the length and width of plates of this circlet are approximately equal; next to the stem impression the surface slopes downward for a short distance, but in the distal area it lies in the basal plane of the cup. Each of the BB has an area approximately equal to that of the IBB circlet; the pB is very noticeably wider, however, and a little shorter than the others, and it is heptagonal instead of hexagonal like the other BB;

the proximal parts of the BB lie tangent to the basal plane of the cup.

The RR are subequal pentagonal plates with nearly straight longitudinal profile and an abrupt angulation at the border of the facet area. The facet occupies the full width of the RR, but in some plates the ends of the transverse ridges are set a little outward from the summits of the interradial sutures. The outer ligament area is short, moderately deeply excavated, and carries a wide, strongly marked ligament pit; an outer marginal ridge is not distinctly seen, the border of the facet area being apparently indicated only by an abrupt curvature. The transverse ridge is narrow, sharp-crested, and continuous, without a depression adjacent to the ligament pit. The inner ligament area is short and almost perfectly plane, being interrupted only by the narrow intermuscular furrow and by a pair of low ridges running parallel to the transverse ridge at about the mid-length of the area; faint growth lines parallel to the lateral and inner edges of the plates are discernible in the muscle areas. An angle of approximately 90° separates the planes of the outer and inner ligament areas, and with the RR in normal position in the cup, the slope of the inner ligament area is slightly but distinctly inward. A single large anal plate, with width approximately equal to the length, rests on the truncated tip of the pB; it is hexagonal in outline, but the basal edge and two lower sides are distinctly longer than the upper borders, more than three-fourths of the area of the plate being included in the dorsal cup. The stem impression is strongly pentagonal in outline and it shows 6 or 7 very short crenellae at the outer edge on each side of the pentagon. The arms and anal sac belonging to this species are not known. The surface is ornamented by a delicate pattern of fine granules, closely spaced and visible only under magnification of a microscope.

Measurements of the holotype specimen, in millimeters, are as follows: height of dorsal cup, 77.0; width of the cup, 22.0; height of basal concavity, 1.2; width of stem impression, 3.6; width of IBB circlet, 10.0; length of raB, 8.7; width of raB, 9.4; length of aR, 6.9; width of aR, 16.2; facet angle, about 45°.

Remarks.—The dorsal cup of *A. dilatus* is more like that of

A. harii Miller and Gurley than those of other described species. It is readily distinguished from this and other known representatives of the genus from the Missouri series near Kansas City, by its unusually broad, low form, and by its surface decoration, as well as by details in the shape of the RR.

Occurrence.—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 4604, railroad cut five miles west of Strohm, Okla. Collected by Paul McGuire.

Types.—Holotype, McGuire collection no. 460412; paratypes, no. 460412a (partially restored cup). In addition, several dissociated radial and basal plates are identified as belonging to this species. Plastotypes, Kansas Univ. no. 460412.

Genus OKLAHOMACRINUS Moore, n. gen.

Dorsal cup extremely depressed, consisting of a nearly flat, straight-sided pentagon with hollowed base. The height of the cup, measured from the basal plane to the transverse ridge of one of the anterior RR, is one-fifth or less of the greatest width. IBB five, forming a slightly stellate pentagon, in the deepest part of the basal concavity; the distal portions flare downward, and on the interior of the cup this circlet forms a cone that in some specimens is distinctly higher than the radial facets. The IBB are not visible in side view of the cup. BB five, subequal, and hexagonal in outline, except the pB which is heptagonal; the proximal portion of these plates flares strongly downward, but the middle and distal areas are horizontal or slope somewhat upward. In some specimens the distal tips of the BB are clearly visible in side view of the cup, but in others they are just barely visible. The RR are subequal, pentagonal plates that lie essentially horizontal, their mid-portion being tangent to the basal plane of the cup. Because of the flat position of the RR, the interradial suture faces diverge distally and converge proximally at an unusual rate; projected toward the center of the cup these lines approximately define fifths of a great circle, with angles between the lines amounting to 72°; the angles between the sides and the summit lines of the RR, at the upper corners of these plates are about 54°. The facets are equal to the greatest width of the RR;

transverse ridge strong, outer ligament area generally deeply excavated and in a subvertical position, inner ligament area short and sloping gently outward. To be noted is the fact that if the RR were inclined upward, as in most crinoid cups, the plane of the inner part of the facets would then slope strongly inward. The transverse ridges of the three anterior RR lie parallel to the basal plane of the cup, but the two posterior RR slope a little upward from the plane defined by the others. A single quadrangular anal plate that is much longer than wide separates the posterior RR and rests on the truncated extremity of the pB.

The arms curve outward and apparently downward from the nearly flat dorsal cup. They are composed of uniserially arranged segments with a wide, short quadrangular IBr_1 in each ray that is followed by a much smaller triangular axillary IBr_2, these two plates being joined by nearly immovable sutures and evidently forming a single functional unit; the two IBr just mentioned are commonly found attached together. So far as known, there is only one bifurcation of each ray, making ten arms in all. The IIBr are somewhat trapezoidal in form and they are arranged in structural pairs, like the IBr, by smooth articular surfaces between the two members, whereas the joints between successive pairs are marked by transverse ridges, ligament pits and muscle areas. A tubular anal sac composed of rows of plates with respiratory pores along their sutures belongs to this crinoid, but the shape and height of the entire tube are not known. The stem is distinctly pentagonal in cross section. It has thickened nodal segments that bear five elliptical scars of cirri and thin internodal segments.

Remarks.—This interesting and distinctive crinoid seems not to resemble closely any other known Upper Carboniferous or Permian crinoid. *Paraburs acrinus* Wanner from the Permian of Timor has a very depressed cup of strongly pentagonal outline, a hollowed base and one anal in the cup, but in spite of this there is little real resemblance to *Oklahomacrinus*; the stem of *Paraburs acrinus* is round, and the arms, which rise vertically from the facets, branch two or more times in each ray. *Benthocrinus* Wanner, also from the Permian of Timor, has an extremely de-

pressed cup with a deeply concave base and one anal plate, but it differs from *Oklahomacrinus* in having a large round stem, very much reduced BB, and greatly thickened RR of a form that is different from these plates in *Oklahomacrinus*.

Comparative study indicates that the new genus here described is most closely related to *Aesiocrinus* Miller and Gurley, for, in spite of the very different appearance of the dorsal cup, there are numerous structural similarities. Both genera have a pentagonal stem and in both the radial facets are notably short, with the plane of the inner ligament area meeting the plane defined by the longitudinal ridge and the proximal tip of the radial distinctly less than a right angle. Because of the bowl-shaped form of the dorsal cup of *Aesiocrinus*, with the RR in a somewhat steeply inclined position, the plane of the inner parts of the facets slopes distinctly inward. The supine position of the RR in *Oklahomacrinus*, however, makes the inner ligament areas actually slope outward. Isolated RR of *Oklahomacrinus* and *Aesiocrinus* can be distinguished only by observing the sharper angles between the summit line and the lateral suture faces in *Oklahomacrinus*. It is the habit of the arms in *Aesiocrinus* to spread outward in approximately horizontal position from the cup, rather than in an erect cluster close to the anal tube, and this is very evidently a peculiarity of *Oklahomacrinus*. Some species referred to *Aesiocrinus*, such as *A. barydactylus* (Keyes) and *A. lykinsi* Butts, have only five unbranched arms, but in other described species the arms fork on the second primibrach, as in *Oklahomacrinus*. Both of the genera under consideration have uniserial arms, a tubular anal sac, and one anal plate in the dorsal cup. All of these resemblances, especially the distinctive nature of the radial facets, are believed to indicate genetic relationship. *Oklahomacrinus* is the more specialized genus, and it was apparently derived from *Aesiocrinus* or a closely similar ancestral form.

Occurrence.—Upper Des Moines series to the top of the Virgil series, Pennsylvanian (Upper Carboniferous); Oklahoma and Kansas.

Genotype. *Oklahomacrinus supinus* Moore, n. sp.

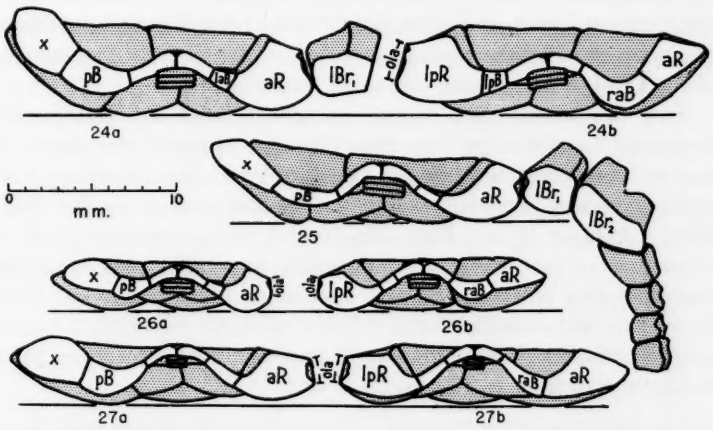
OKLAHOMACRINUS SUPINUS Moore, n. sp.

Plate IX, figures 5a–d; text figures 24a, b, 28a–d

Description of this species is based on a complete dorsal cup to which IBr are attached in three of the rays. The general form and structure of the cup conforms to the description given in definition of the genus. The cone on the inside of the cup, formed by the downward sloping IBB, is distinct but low, reaching upward only to about one-half of the height of the radial facets. Plates of the BB circlet are characterized by very strong longitudinal curvature and moderate transverse convexity. The basal plane of the cup is tangent to the mid-portion of some of these plates and lies a fraction of a millimeter below others; this plane is also tangent to a portion of the RR, but because of slight irregularity, fails to touch all of them (see Figs. 24a, b). The proximal portions of the BB slope strongly downward, but the distal extremities slope upward and this part of the plates is clearly visible in side view of the cup. The distal suture faces of the BB curve outward slightly and the adjoining faces of the RR show a correspondingly gentle concave form.

Along the midline of each R, the proximal portion flares slightly downward, the central part is tangent or parallel to the basal plane of the cup, and the distal part curves very abruptly about 90° to the edge of the outer ligament area. There is a moderately strong but uniform transverse curvature of these plates which produces a broad angular furrow along the line of the interradial sutures. The outer ligament area of the facet is moderately excavated, its length in the midportion being about one-fifth of its total width; its outer edge is distinct but is not marked by an outer marginal ridge; a deep short ligament pit lies at the inner edge of the area, next to the transverse ridge, which consists primarily of a sharp angulation between the outer and inner ligament areas. The inner ligament area has a very gentle outward slope, the angle between its plane and that defined by the margin of the outer ligament area being about 115°; the maximum length of the inner ligament area is hardly greater than that of the outer, and there is no flangelike inward projection at the inner border.

A shallow intermuscular furrow extends from the barely perceptible intermuscular notch at the inner border of the facets to the longitudinal ridge; the muscle areas are separated from the long but shallow oblique furrows by a ridge that bifurcates near the intermuscular furrow. Characters of the facets are especially



FIGS. 24–27. Median sections of dorsal cups belonging to species of *Oklahomacrinus*. *24a*, Section of the dorsal cup of *Oklahomacrinus supinus*, n. sp., through the pB, the aR, and an attached IBr, shaded areas representing parts of the cup beyond the plane of the section; *24b*, similar section through the lpR and raB; both drawings based on the holotype (*ola*, outer ligament area). *25*, Section of the dorsal cup and anterior ray of *Oklahomacrinus loeblichi*, n. sp., through the pB and aR, based on the holotype. *26a*, Section of the dorsal cup of *Oklahomacrinus stevensi*, n. sp., through the pB and aR; *26b*, similar section through the lpR and raB; both drawings based on the holotype (partly restored). *27a*, Section of the dorsal cup of *Oklahomacrinus bowsheri*, n. sp., through the pB and aR; *27b*, similar section through the lpR and raB; both drawings based on the holotype (partly restored).

well shown by a dorsal cup (Plate IX, figs. 1a–c) from an unknown source that was found among miscellaneous unlabeled fossils at the University of Kansas.

The anal x is an elongate, quadrangular plate with length nearly three times the width; the surface of the proximal two-thirds slopes very gently upward in the plane of the adjacent RR,

but the distal one-third curves very abruptly about 90° from the plane of the other part of the plate and rises slightly above the facets of the adjoining RR.

The three attached IBr_1 are short trapezoidal segments, which are attached so as to conceal entirely the outer ligament area of the RR that bear them, and there is a very broad notch between the remaining part of the proximal facet of the IBr and the inner ligament area of the radial facet. The distal articular surface of the IBr is a plain facet, devoid of any markings.

Two dissociated RR in the collection from the Brownville limestone near Strohm (see Figs. 38a–e) are nearly the same in size as corresponding plates in the dorsal cup just described, but differ in shape, especially as shown by the median profile (Fig. 38b). Another R (see Figs. 39a–b) and B that are identified as belonging to this genus are more than one-half larger than the corresponding plates of the type specimen of *O. supinus* and they have somewhat similar form. None of these dissociated plates are identified as belonging to *O. supinus*, although they may indicate variations in this species.

Measurements of dorsal cups of species of Oklahomacrinus, in millimeters, based on holotypes

SPECIES OF OKLAHOMACRINUS	SUPINUS	LOEBLICHI	BOWSHERI	STEVENSI
Height of cup[1]	4.0	2.7	2.8	2.0
Greatest width of cup	20.0	19.8	18.9	14.8
Ratio of height to width	0.20	0.14	0.15	0.13
Height of basal concavity	2.7	2.6[a]	2.8	2.1
Ratio of height of basal concavity to height of cup	0.68	0.96	1.00	1.05
Greatest width IBB circlet	5.5	5.0[a]	3.0	3.0
Width of stem impression	2.3	2.7	1.3	2.0
Length of basal (raB)	6.3	5.5	3.6	3.7
Width of basal (raB)	5.2	4.2	2.5	3.0
Length of radial (aR)[2]	6.0	6.0	6.0	4.4
Length of outer ligament area	2.2	1.6	1.5	1.2
Length of transverse ridge	12.0	11.0	11.0	8.4
Width of radial (aR)	13.5	12.3	12.0	10.1

[a] Approximate.

[1] Measured from basal plane to transverse ridge on anterior radial.

[2] Measured along curvature of plate.

The surface of all of the plates is smooth, without any perceptible ornamentation.

Measurements of the holotype of *O. supinus* and of other species that are here assigned to the genus are given in the tabulation at bottom of page 260.

Remarks.—This species differs from *O. loeblichi*, n. sp., in the slightly greater height of the dorsal cup and the more tumid appearance of the BB. The RR of *O. supinus* are relatively much thicker and the outer ligament areas are longer and less deeply excavated than in the other species mentioned.

Occurrence.—Upper member of the Brownville limestone, Wabaunsee group, Virgil series, upper Pennsylvanian (Upper Carboniferous); loc. 4604, five miles west of Strohm, Oklahoma.

Type. Holotype, Paul McGuire collection no. 460410. Plastotype, Kansas Univ. no. 460410.

OKLAHOMACRINUS LOEBLICHI Moore, n. sp.

Plate IX, figures 2a,b; text figures 25, 29a–d, 30a–c, 31a,b, 34a–e, 35a–e, 36a–e, 37a–c

This species is described on the basis of an incomplete crown preserved in soft clay shale. Although some of the plates were disjoined, their position was not greatly changed, so it was readily possible to reunite them in proper relation. Before the plates were mounted together study and measurements of each type were made separately.

The size and general appearance of the calyx of *O. loeblichi* are almost identical with those of *O. supinus*, but the cup is distinctly flatter, the ratio of height to width being 0.12 in this species as compared with 0.20 in *O. supinus*.

The five IBB form a cone that measures 6 mm. in diameter and 2 mm. in height; the plates of this circlet flare rather evenly downward, and the proximal two-fifths of these is occupied by the stem impression; the thickness of these plates is 1 mm. at the proximal tip, but only about 0.5 mm. at the distal extremity; the distal sutures are distinctly excavated but the others are plane. The BB closely resemble those of *O. supinus* in convexity and in proportion, but on the whole are less bulbous.

The RR have a width that exceeds twice the length; their shape differs from that of *O. supinus* only in the more compressed upper angles and in the distinctly shorter outer ligament area. The anal plate, which is 2 mm. wide and 5 mm. long, has a distinctly concave surface near the distal extremity but is otherwise plane.

The IBr_1 is a quadrangular segment with trapezoidal form; the transverse convexity corresponds to that of the RR, being swollen in the mid-portion but produced laterally in two flangelike extensions. The lower articular surface bears a transverse ridge, a deep ligament area, and muscle areas like those of the corresponding R, but the articular surface on the distal end is smooth. The IBr_2 is a triangular axillary plate that is attached somewhat rigidly to the IBr_1; the upper articular faces bear strong transverse ridges, deep outer ligament areas, and relatively plane muscle areas. The two $IIBr_1$ of each ray are shaped somewhat like the head of an ax, with broad blade directed toward the outer side of the ray and a narrower one toward the inner side; the distal articular surface is smooth and it occupies only the central part of the plate. Succeeding IIBr are trapezoidal segments with

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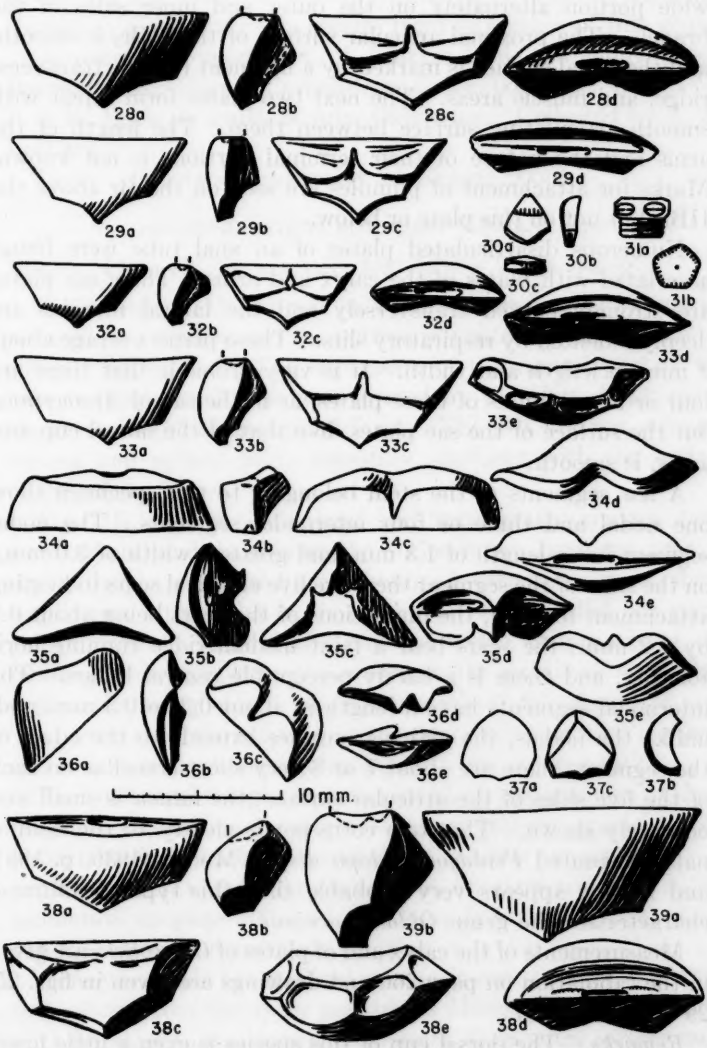
FIGS. 28–39. Drawings of plates of species of *Oklahomacrinus*, n. sp. *28a–d*, Exterior, side, interior, and top views of the raR of *Oklahomacrinus supinus*, from the holotype specimen. *29a–d*, Exterior, side, interior, and top views of the aR of *Oklahomacrinus loeblichi*, n. sp., from the holotype specimen. *30a–c*, Exterior, side, and distal views of an IB of *Oklahomacrinus loeblichi*, from the holotype. *31a,b*, Columnals from the holotype of *Oklahomacrinus loeblichi*, respectively showing a side view of a nodal and three internodal segments (with elliptical scars of cirri attachments on the nodal), and the articular face of an internodal. *32a–d*, Exterior, side, interior, and top views of the raR of *Oklahomacrinus stevensi*, n. sp., from the holotype. *33a–e*, Exterior, side, interior, top, and bottom views of the raR of *Oklahomacrinus bowsheri*, n. sp., from the holotype. *34a–e*, Exterior, side, interior, top, and bottom views of a first primibrach of *Oklahomacrinus loeblichi*, from the holotype. *35a–e*, Exterior, side interior, top, and bottom views of a second primibrach (axillary) of *Oklahomacrinus loeblichi*, from the holotype. *36a–e*, Exterior, side, interior, top, and bottom views of a first secundibrach of *Oklahomacrinus loeblichi*, from the holotype. *37a–c*, Exterior, side, and interior views of a basal plate of *Oklahomacrinus loeblichi*, from the holotype. *38a–e*, Exterior, side, interior, top, and bottom views of a dissociated radial from the Brownville limestone (loc. 4604), identified as *Oklahomacrinus* sp. *39a, b*, Exterior and side views of a large radial from the Brownville limestone (loc. 4604), identified as *Oklahomacrinus* sp.


28a
28b
28c
28d
29a
29b
29c
29d
30a
30b
30c
31a
31b
32a
32b
32c
32d
33a
33b
33c
33d
33e
34a
34b
34c
34d
34e
35a
35b
35c
35d
35e
36a
36b
36c
36d
36e
37a
37c
37b
10 mm.
38a
38b
38c
38e
38d
39b
39a

FIGS. 28–39.

wide portion alternately on the outer and inner sides of the branch. The proximal articular surface of the $IIBr_2$ is smooth, and the distal surface is marked by a ligament furrow, transverse ridge, and muscle areas. The next two plates form a pair with smooth articulating surface between them. The length of the arms and the nature of their terminal portions is not known. Marks for attachment of pinnules are seen on the Br above the $IIBr_1$ but not on this plate or below.

Numerous disarticulated plates of an anal tube were found associated with plates of the calyx and arms. These sac plates are strongly curved transversely and the lateral margins are deeply indented by respiratory slits. These plates average about 2 mm. in length and width. It is very probable that there are four or five columns of these plates, as in the sac of *Aesiocrinus*, but the surface of the sac plates, like that of the dorsal cup and arms, is smooth.

A few segments of the stem belonging to this specimen show one nodal and three or four internodal segments. The nodal segment has a length of 1.3 mm. and greatest width of 3.0 mm.; on the sides of the segment there are five elliptical scars indicating attachment for cirri, the dimensions of the scars being about 0.8 by 1.2 mm.; the scars bear a faint median ridge running horizontally, and there is a barely perceptible central lumen. The internodal segments have a length of about 0.3 to 0.5 mm. and, unlike the nodals, the articular surface extends to the edges of the segment; there are about 7 or 8 very short crenellae on each of the five sides of the articular surface; the lumen is small and obscurely shown. The stem corresponds closely to the columnals designated *Pentagonocyclopa dispar* Moore (1939, p. 193), and it now appears very probable that this type of columnal characterizes the genus *Oklahomacrinus*.

Measurements of the calyx and of plates of *O. loeblichi* are given in the tabulation on page 260 and drawings are given in figs. 25, 29–31, and 34–37.

Remarks.—The dorsal cup of this species is even a little lower than that of *O. bowsheri* and *O. stevensi*; it is distinguished from these species by the smooth surface of its plates. The thinness

of the RR and lower Br laterally, which gives them a flangelike character, distinguish this species from any other of this genus.

Occurrence.—Upper part of Francis shale, Missouri series, Pennsylvanian (Upper Carboniferous); loc. 6058, sec. 4, T. 3 N:, R. 6 E., brick pit south of Ada, Oklahoma. Collected by A. R. Loeblich.

Types. Holotype, University of Kansas 60581.

OKLAHOMACRINUS BOWSHERI Moore, n. sp.

Plate IX, figures 4a,b; text figures 27a,b, 33a–e

The incomplete dorsal cup, on which description of this species is based, is very low and the outline in ventral or dorsal view, is sharply pentagonal. The depression of the central part of the base is pronounced; the cone formed by the IBB circlet rising above the level of the radial facet. The BB are not strongly convex and appear fairly smoothly confluent with the surface of the joining plates.

The RR are relatively long and very gently convex, both transversely and longitudinally. The outer ligament area is short, deeply excavated, and bounded externally by a sharp angulation. The sides of the anal x are not parallel but curve gently outward so that the greatest width, 2 mm., is at the midlength of the plate, the width at the proximal and distal extremities being only 1 mm.; the length of this plate is 4 mm. The outline of the stem is pentagonal, with rounded corners, and it is very small, measuring only 1.3 mm. in diameter.

The surface of the plates is decorated by low granules or short irregular discontinuous ridges that are closely spaced. This pattern is visible with the unaided eye, but it is not coarse.

Measurements of the holotype of *O. bowsheri* are given in the tabulation on page 260, and drawings showing the form of the cup in cross section appear in fig. 27.

Remarks.—This lower Virgil species is most closely similar to *O. loeblichi*, from the upper part of the Missouri series. The RR of *O. bowsheri* appear somewhat thinner, their outer surface more evenly curved, so that a flangelike appearance of the lateral areas is lacking, and the short outer ligament area is more depressed.

The surface ornamentation resembles that of *O. stevensi*, but otherwise the appearance of the cups of these two species differs rather evidently, for in one the surface contour is fairly smooth but in the other the plates of the basal and radial circlets appear bulbous. The very minute stem, and possibly the biconvex outlines of the anal plate distinguish this species from any others observed.

Occurrence.—Nelagoney formation, from a limestone a few inches thick that occurs about 35 feet below the Wildhorse limestone in the upper middle part of this formation, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 6066, in the northwest quarter of sec. 21, T. 22 N., R. 10 E., Osage County, Oklahoma, north of Skiatook-Hominy road, about 15 miles west of Skiatook. Collected by Arthur L. Bowsher.

Type. Holotype, University of Kansas, no. 60662.

OKLAHOMACRINUS STEVENSI Moore, n. sp.

Plate IX, figures 3a–c; text figures 26a,b, 32a–d

The dorsal cup of this species is small and low, the ratio of height to width being the same as in *O. bowsheri*. The basal concavity is strongly developed but not quite so high as in the associated species from the Nelagoney formation. The BB and RR are strongly convex, as in *O. supinus*. The outer ligament areas are only moderately excavated, and are not sharply marked off by an angulation from the adjoining portion of the plate. The anal plate is relatively wide and short, measuring 1.5 mm. in width and 3 mm. in length; its straight sides are parallel. The proximal stem segments are rounded-pentagonal in form, and proportionally the diameter of the stem is as large as in *O. loeblichi*.

The surface of the cup is ornamented by a well defined pattern of low but sharp pimple-like granules; the rounded base of these granules has an average diameter of about 0.1 mm. and the average space between adjacent granules is about 0.3 mm.

Measurements of the dorsal cup of this species are given in the tabulation on page 260, and cross-sections of the cup are shown in fig. 26.

Remarks.—The general form of the dorsal cup in *O. stevensi* is most like that of *O. supinus*, but the latter is much larger and has smooth, unornamented surface. The granulose ornamentation is distinctly different from that of *O. bowsheri*, the plates are much more convex, and the stems much larger. The species is named for Bob Stevens, of Gorham, Kans., formerly of the University of Tulsa, who has contributed many Oklahoma crinoids for my study.

Occurrence.—Nelagoney formation, from thin limestone about 35 feet below the Wildhorse limestone, in upper middle part of the formation, Virgil series, Pennsylvanian (Upper Carboniferous); loc. 6066, northwest quarter sec. 21, T. 22 N., R. 10 E., north of Skiatook-Hominy road, about 15 miles west of Skiatook, Osage County, Oklahoma. Collected by Arthur E. Bowsher.

Type.—Holotype, Kansas. Univ., no. 60663.

REGISTER OF LOCALITIES

Nebraska, Gage County

4605—Grant shale member of the Winfield limestone, Chase group, Big Blue series, Lower Permian; northwest corner of southwest quarter of sec. 20, T. 1 N., R. 6 E., southeast of Odell; collection by H. Allison Tourtelot, University of Nebraska. *Nebraskacrinus tourteloti*, holotype.

Kansas, Douglas County

6022—Plattsmouth limestone member of the Oread limestone, Shawnee group, Virgil series, Pennsylvanian (Upper Carboniferous); old quarry on south bank of Kansas River, 50 yards west of Lecompton depot on Santa Fe railroad, northeast quarter sec. 33, T. 11 S., R. 18 E.; collection by Raymond C. Moore, Arthur Bridwell. *Utharocrinus oreadensis*, holotype.

Kansas, Jefferson County

4572—Coal Creek limestone member of the Topeka limestone, Shawnee group, Virgil series, Pennsylvanian (Upper Carboniferous); outcrop on Crooked Creek in field west of north-south road, northeast quarter sec. 29, T. 8 S., R. 19 E., about 8 miles north of Oskaloosa; collection by Raymond C. Moore, Arthur Bridwell. *Utharocrinus topekensis*, holotype.

Kansas, Lyon County

6025—Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); near Emporia (precise horizon and locality unknown); collection by Alva J. Smith. *Pachylocrinus bellirugosus*, holotype.

Kansas, Riley County

744—Fort Riley limestone member of the Barneston limestone, Chase group, Big Blue series, Lower Permian; near center of sec. 33, T. 7 S., R. 6 E., about 1 mile east of Walsburg; collection by W. H. Twenhofel. *Pachylocrinus twenhofeli*, holotype and paratypes.

5902—Grant shale member of the Winfield limestone, Chase group, Big Blue series, Lower Permian; sec. 1, T. 9 S., R. 4 E., about 1 mile east of Bala; collection by J. Mark Jewett and Raymond C. Moore. *Nebraskacrinus tourteloti*, paratype.

Kansas, Butler County

5909—?Fort Riley limestone member of the Barneston limestone, Chase group, Big Blue series, Lower Permian; vicinity of Augusta (precise horizon and locality uncertain); collection by student, University of Wichita, obtained by J. Mark Jewett. *Pachylocrinus colubrosus*, holotype and paratype.

Oklahoma, Pontotoc County

6058—Francis formation (upper part), Missouri series, Pennsylvanian (Upper Carboniferous); quarry of the Ada Brick Company, in sec. 4, T. 3 N., R. 6 E., about 1 mile south of Ada; collection by A. R. Loeblich. *Oklahomacrinus loeblichi*, holotype.

Oklahoma, Osage County

6066—Thin limestone in shale about 35 feet below Wildhorse limestone member of the Nelagoney formation, lower Virgil series, Pennsylvanian (Upper Carboniferous); in northwest quarter of sec. 21, T. 22 N., R. 10 E., about 15 miles west of Skiatook, Okla., on road to Hominy; collection by Arthur L. Bowsher, L. R. Laudon, John D. Ewers, Paul McGuire, and Raymond C. Moore. *Plaxocrinus politus*, holotype; *Oklahomacrinus bowsheri*, holotype; *Oklahomacrinus stevensi*, holotype.

4582—Brownville limestone, Wabaunsee group, Virgil series, Pennsylvanian (Upper Carboniferous); outcrops near stockyards and tank at Strohm station on the A. T. and S. F. railway, southwest quarter of sec. 16, T. 25 N., R. 7 E., about 10 miles northeast of Fairfax; collection by Paul McGuire. *Plaxocrinus virginarius*, holotype; *Plaxocrinus modestus*, holotype.

4578—Brownville limestone; cut on A. T. and S. F. railway at Keefe, Okla., 7 miles west of Strohm and 3 miles east of Fairfax, near center of the northwest quarter of sec. 10, T. 24 N., R. 6 E.; collection by Paul McGuire, E. L. Banion, and Raymond C. Moore. *Cibolocrinus banioni*, holotype and paratype. *Graphiocrinus delicatulus* holotype. *Pachylocrinus mcguirei*, plates. *Plaxocrinus praevalens*, plates.

4604—Brownville limestone, cut on A. T. and S. F. railway 5 miles west of Strohm, Okla., center south line southeast quarter of sec. 35, T. 25 N., R. 6 E.; collection by Paul McGuire, E. L. Banion, and Raymond C. Moore. *Pachylocrinus mcguirei*, holotype and paratypes. *Plaxocrinus orthodoxus*, holotype. *Plaxocrinus praevalens*, holotype. *Perimestocrinus subtilis*, holotype. *Aesiocrinus dilatus*, holotype, and paratypes (plates). *Trautscholdicrinus mcguirei*, holotype. *Oklahomacrinus supinus*, holotype. *Utharocrinus quinquacutus*, holotype.

5933—Brownville limestone; cut on A. T. and S. F. railway, 6 miles west of Strohm, Okla., northwest quarter southwest quarter of sec. 2, T. 24 N., R. 6 E.; collection by Paul McGuire. *Plaxocrinus modestus*, paratype.

5936—Brownville limestone; cut on A. T. and S. F. railway, 4 miles west of Strohm, Okla., near southwest corner of sec. 25, T. 25 N., R. 6 E.; collection by Paul McGuire. *Delocrinus* and fragmentary remains.

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EXPLANATION OF PLATE V

(All figures natural size, except as indicated)

PAGE

Nebraskacrinus tourteloti, n. gen., n. sp. 199

1—Holotype, Nebraska Geol. Survey coll. (Kansas plastotype no. 46051); Winfield limestone, Lower Permian, near Odell, Neb. *a*, Calyx and lower part of arms from the right side, showing the bulging posterior (left margin of photograph) and a portion of the large anal sac; *b*, posterior view of the calyx, with the arm branches above the IAx of the right posterior ray removed so as to show more clearly the lower part of the sac; *c*, dorsal view, showing the round stem impression with pentastellate lumen; *d*, interior side of IIBr with pinnule (at left), showing covering plates on the ambulacral groove of the pinnule, from right posterior ray (×2).

Trautscholdicrinus mcguirei, n. sp. 196

2—Holotype, McGuire coll. (Kansas plastotype no. 460415); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view of calyx, with posterior interradius directed upward, the squarely truncated pB being visible just above the attached stem; *b*, posterior view of the obliquely flattened crown; *c*, top of the crown, posterior side at left, showing the infolded arrangement and heterotomous branching of the arms.

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Cibolocrinus banioni, n. sp 191

3—Holotype, Kansas Univ. coll. no. 45784; Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 7 miles west of Strohm, Okla. *a*, View of dorsal cup from the left side, specimen partly reconstructed by addition of dissociated radials and a basal plate; *b*, ventral view, the basal plate at the bottom, in position of pB, is not truncated distally and is not the pB.

4—Paratype, Kansas Univ. coll. no. 45785; from same horizon and locality as the holotype. *a*, Dorsal view, partially restored, the posterior RR and anal x from one individual, the laR and laB being possibly but not certainly from the same cup; *b*, posterior view, showing the surface ornamentation of the plates and the transversely concave, projecting anal x; *c*, ventral view, showing clearly the normal character of the radial facets of *Cibolocrinus*.

5—A large IBr_1, paratype, Kansas Univ. coll. no. 45786a; from same horizon and locality as the holotype. *a*, Exterior (dorsal) view (×2); *b*, top view, showing wide short ligament pit and other characters resembling the facet of a radial plate (×2); *c*, bottom view (×2).

6—A small IBr_1, paratype, Kansas Univ. coll. no. 45786b; from same horizon and locality as the holotype: *a*, Exterior view (×2); *b*, top view (×2); *c*, bottom view (×2).

7—An axillary arm plate, IBr_2, showing the extremely large angle between the two facets of the upper side and the nearly quadrangular outline of the plate, paratype, Kansas Univ. no. 45786c; from same horizon and locality as the holotype. *a*, Exterior view (×2); *b*, top view, showing the two ligament pits (×2); *c*, bottom view (×2).

8—An IBB circlet, interior view showing the two large and one smaller plate and the triangular opening at the center, paratype no. 45787, Kansas Univ. coll.; from the same horizon and locality as the holotype (× 1.7).

Aesiocrinus dilatus, n. sp 252

9—Holotype, McGuire coll. (Kansas Univ. plastotype no. 460412); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view of incomplete cup, showing the pentagonal stem impression, very broad pB and anal x plates, and fine granulose ornamentation (×2); *b*, ventral view, showing the short facets, the plane of the inner ligament area approximately at right angles to that of the outer ligament area, (×2); *c*, posterior view, indicating the very low height of the cup, (×2).

10—Paratype, Kansas Univ. coll. no. 460422, consisting of assembled RR and B, shape of cup, including all of posterior part, represented in plaster; same horizon and locality as the holotype. *a*, Dorsal view, and the assembled plates in the position of the aR, laR and laB; *b*, side view of assembled plates.

EXPLANATION OF PLATE VI

(All figures natural size, except as indicated)

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Pachylocrinus twenhofeli, n. sp. 217

1—Holotype, an incomplete crown with attached proximal stem segments, Kansas Univ. coll. no. 744-1; Fort Riley limestone member of the Barneston limestone, Lower Permian, near Walsford, Riley County, Kans. *a*, Dorsal view of the obliquely crushed specimen, the laR centrally located above, view nearly normal to the BB circlet (×2); *b*, view of the left side of the crown, the posterior interradius at the right margin, view parallel to basal plane of the cup and showing fairly well the actual shape of the cup.

2—A paratype, Kansas Univ. coll. no. 744-3, from the same horizon and locality as the holotype; side view of cup, the somewhat displaced RA and anal x plates visible at the right margin, (×2).

3—Portion of stem (*Cyclocyclopa twenhofeli*) found associated with this species and with little doubt belonging to it, Kansas Univ. coll. no. 744-8; *a*, Side view showing alternating nodal and internodal columnals, some of the former with attached cirri (×2); *b*, articular face of columnal at bottom of the stem fragment (×2).

4—A shorter piece of the stem, also from the same horizon and locality as the holotype, Kansas Univ. coll. no. 744-7. *a*, Side view, showing cirri (×2); *b*, articular face of top columnal of the series (×2).

Pachylocrinus colubrosus n. sp. 220

5—Anal sac of paratype, Kansas Univ. no. 59092; from the ?Fort Riley limestone, Lower Permian, near Augusta, Kans. *a*, View of the left side, showing clearly the looped form that is formed by sharp curvature at the top, the distal part descending in a course parallel to the vertically ascending proximal part, the latter at right, and showing the transverse ridges between respiratory slits of the tube (×2); *b*, view of the anterior side, the descending part of the tube being seen above an orifice that is believed to be the anal vent, connected, however, with the proximal part of the sac (×2); *c*, view of the right side (×2.4).

Pachylocrinus mcguirei, n. sp. 205

6—Portion of the anal sac of a paratype, McGuire coll. (Kansas Univ. plastotype no. 46047); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Side view, showing somewhat serrate ridge at top and the adjoining row of transverse slits and ridges that cross the sutures between columns of plates, broken distal end at left, (×2); *b*, top view, showing grooved form with bordering keels, respiratory slits lacking, distal portion downward in the photograph (×2).

7—An IBB circlet (*Pentexobasis mcguirei*) that almost certainly belongs to this species, McGuire coll. no. 460421a; from same horizon and locality as the types of *Pachylocrinus mcguirei*. *a*, Exterior (dorsal) view, showing the subpentagonal stem impression and deep ligament pits of the suture faces (×2); *b*, side view (×2).

8—Another IBB circlet, McGuire coll. no. 460421b; from the same horizon and locality. Exterior view (×2).

9—IBB circlet, McGuire coll. no. 460421c; from the same horizon and locality. Interior view (×2).

10—Dissociated basal plate (*Schedaglaopolygonum mcguirei*), McGuire coll. no. 460419a; from the same horizon and locality. *a*, Distal view, showing convexity, surface markings, and excavated suture faces (×2); *b*, interior view (×2).

11—Another basal plate, McGuire coll. no. 460419b; from the same horizon and locality. *a*, Distal view (×2); *b*, exterior view, showing smooth surface and slight flange along lateral and distal margins (×2).

12—Portion of stem (*Cyclocyclopa mcguirei*) corresponding in character to proximal columnals attached to cups of *Pachylocrinus mcguirei*, McGuire coll. no. 460418a; from same horizon and locality. The stem consists of alternating nodals and internodals arranged in pairs, but no cirri or scars of attachment for cirri are observed (×2.3).

13—Holotype, one of the most perfect dorsal cups, McGuire coll. (Kansas Univ. plastotype no. 46043); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Posterior view (×1.5); *b*, anterior view, showing the strongly marked differentiation in slope of the BB and RR circlets and furrows along the interradial sutures (×1.5); *c*, ventral view, showing the outwardly set position of the transverse ridges of the facets and notches at the summit of the interradial sutures (×1.5); *d*, dorsal view (×1.5).

14—Paratype, a dorsal cup with portions of arms attached, varying from the normal examples of the species in the much greater height of the basal concavity and in having distinctly rugose plates, McGuire coll. (Kansas Univ. plastotype no. 46044); from same horizon and locality as the holotype. *a*, Dorsal view (×1.5); *b*, posterior view (×1.5).

15—Paratype, a nearly complete crown that differs from normal examples in form of the dorsal cup and in lacking axillary IBr_1 in two rays, McGuire coll. (Kansas Univ. plastotype no. 46041); from same horizon and locality as the holotype. *a*, Anterior side, the most clearly shown IAx being that of the right anterior ray; *b*, dorsal view, slightly oblique so as to show the arm structure of the posterior part of the crown.

16—Limestone fragment containing several arms from the upper part of a crown of this species, McGuire coll. no. 460418b; from the same horizon and locality as the holotype.

EXPLANATION OF PLATE VII

(All figures ×2)

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Utharocrinus quinquacutus, n. sp. 239

1—Holotype, a nearly perfect dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 46048); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view showing the angular pentagonal outline, depression of the posterior interradius, and the five closely spaced spinous BB; *b*, ventral view, with very well preserved markings of the facets; *c*, posterior view, showing the pointed BB, the flaring sides of the cup, and the outward slope of the facets, which are much steeper than in the genotype species.

Utharocrinus oreadensis, n. sp. 242

2—Holotype, a well preserved dorsal cup, Kansas Univ. no. 60221; Plattsmouth limestone member of the Oread limestone, Lecompton, Kans. *a*, Dorsal view, showing position of the BB nodes near the distal extremities of these plates, and indicating the lack of depression of the posterior interradius; *b*, ventral view; *c*, posterior view.

Utharocrinus topekensis, n. sp. 244

3—Holotype, a dorsal cup with spinous BB and steeply sloping sides, Kansas Univ. no. 45721; Coal Creek limestone member of the Topeka limestone, 8 miles north of Oskaloosa, Kans. *a*, Dorsal view, showing the rounded-pentagonal outline of the cup formed mainly by nodose bulges of the RR; *b*, ventral view; *c*, posterior view, showing plates of the anal series in normal position.

Perimestocrinus subtilis, n. sp. 235

4—Holotype, a dorsal cup showing typical characters of the genus except for its unusually low height, McGuire coll. (Kansas Univ. plastotype no. 460411); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view, showing the steep-walled basal concavity; *b*, ventral view; *c*, posterior view, showing the large RA that almost displaces anal x and rt (position indicated by notches) from the cup.

Pachylocrinus bellirugosus, n. sp. 215

5—Holotype, a slightly compressed but excellently preserved dorsal cup with attached portions of the arms, Kansas Univ. no. 60251; Wabaunsee group (exact horizon unrecorded), Pennsylvanian (Upper Carboniferous), near Emporia, Kans. *a*, Posterior view of the incomplete crown, showing the distinctive surface ornamentation of narrow ridges and nodes, anal plates in normal arrangement; *b*, dorsal view; *c*, view of the anterior side, the aR slightly right of the center.

Pachylocrinus colubrosus, n. sp. 220

6—Holotype, a well preserved nearly complete crown, Kansas Univ. no. 59091; ?Fort Riley limestone, Lower Permian, near Augusta, Kans. *a*, Anterior side of the specimen, the right anterior and anterior rays centrally in the view; the keeled arms and long pinnules are shown;

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superposed arm at the top belongs to the paratype specimen. *b*, Posterior side of the crown, showing especially the recurved anal sac in normal position, bending toward the anterior side. *c*, Dorsal view of the cup, the small basal concavity almost filled by proximal stem segments.

Cibolocrinus banioni, n. sp 191

7—IBB circlet (*Triexobasis banioni*), Kansas Univ. no. 45787; Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 7 miles west of Strohm, Okla. Exterior (dorsal) view, showing the vertical or slightly overhanging wall of the stem impression, granulose markings around the small central lumen and absence of crenellae in the impression, and the short distal region of the IBB outside of the stem area. This is the same specimen shown in Plate V, fig. 8.

EXPLANATION OF PLATE VIII

(All figures natural size, except as indicated)

PAGE

Plaxocrinus orthodoxus, n. sp 233

1—Holotype, a dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 46049); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view; *b*, ventral view; *c*, posterior view.

Plaxocrinus virginarius, n. sp 231

2—Holotype, a very well preserved dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 45821); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), at Strohm, Okla. *a*, Dorsal view; *b*, same (×2); *c*, ventral view; *d*, posterior view; *e*, anterior view.

Plaxocrinus modestus, n. sp 227

3—Holotype, a dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 45822); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), at Strohm, Okla. *a*, Dorsal view, showing strongly marked notches at summits of interradial sutures; *b*, ventral view; *c*, posterior view, the posterior interradius narrow and rather sharply concave; *d*, anterior view.

4—Paratype, a dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 59331); Brownville limestone, 6 miles west of Strohm, Okla. *a*, Dorsal view; *b*, ventral view; *c*, posterior view; *d*, anterior view.

Plaxocrinus politus, n. sp 223

5—Holotype, a crown that is complete except for part of the right anterior ray and sac spines, Kansas Univ. no. 60661; from the Nelagoney formation (about 35 feet below Wildhorse limestone member), upper Pennsylvanian (Upper Carboniferous), about 15 miles west of Skiatook, Okla. *a*, Posterior view of crown, showing low dorsal cup, prominent spine-bearing axillary primibrachs, and uniserial segments of upper arms (×2); *b*, anterior view of crown, showing similar features and remnants of anal sac spines above arms (×2); *c*, dorsal view (×2).

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Plaxocrinus praevalens, n. sp. 229

6—Holotype, an incomplete dorsal cup with two slightly displaced primibrach spines, McGuire coll. (Kansas Univ. plastotype no. 460414); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view; *b*, posterior view; *c*, anterior view; *d*, dorsal side of an IBr_1; *e*, ventral view of an IBr_1.

EXPLANATION OF PLATE IX

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Oklahomacrinus sp., n. gen. 255

1—A very well preserved dorsal cup from unrecorded horizon and locality, found in collections of the University of Kansas; probably Pennsylvanian. *a*, Dorsal view, showing the sharply pentagonal outline of the dorsal cup, the horizontal position of the RR, and the single elongate anal plate, (×2); *b*, ventral view, showing the cone of the IBB circlet that rises approximately to the summit of the RR, and the markings of the facets (×2); *c*, anterior view, indicating the extremely flat, disc-like nature of the cup (×2).

Oklahomacrinus loeblichi, n. gen., n. sp. 261

2—Holotype, an incomplete crown, reconstructed from slightly displaced plates preserved in shale, Kansas Univ. no. 60581; Francis formation, upper middle Pennsylvanian (Upper Carboniferous), near Ada, Okla. *a*, Dorsal view of crown, showing the isotomously branching arms and brachial segments with flattened lateral expansions (×2); *b*, oblique view of crown, indicating pendent nature of arms (×1.5).

Oklahomacrinus stevensi, n. gen., n. sp. 266

3—Holotype, an incomplete dorsal cup, Kansas Univ. no. 60663; from the Nelagoney formation (about 35 feet below Wildhorse limestone member), upper Pennsylvanian (Upper Carboniferous), about 15 miles west of Skiatook, Okla. *a*, Dorsal view, showing convexity of plates and their granulose ornamentation (×2); *b*, ventral view (×2); *c*, posterior view (×2).

Oklahomacrinus bowsheri, n. gen., n. sp. 265

4—Holotype, an incomplete dorsal cup, Kansas Univ. no. 60662; from the Nelagoney formation (about 35 feet below the Wildhorse limestone member), upper Pennsylvanian (Upper Carboniferous), 15 miles west of Skiatook, Okla. *a*, Dorsal view, showing the rather evenly confluent surface and broad basal concavity, the anal x widened at its midlength (×2); *b*, ventral view (×2).

Oklahomacrinus supinus, n. gen., n. sp. 258

5—Holotype, a perfect dorsal cup with three attached IBr, McGuire coll. (Kansas Univ. plastotype no. 460410); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 5 miles west of Strohm, Okla. *a*, Dorsal view (×2); *b*, ventral view, showing the wide gap between apposed facets of the RR and IBr_1 (×2); *c*, posterior view; *d*, oblique view of the dorsal side showing convexity of plates and the basal concavity (×1.5).

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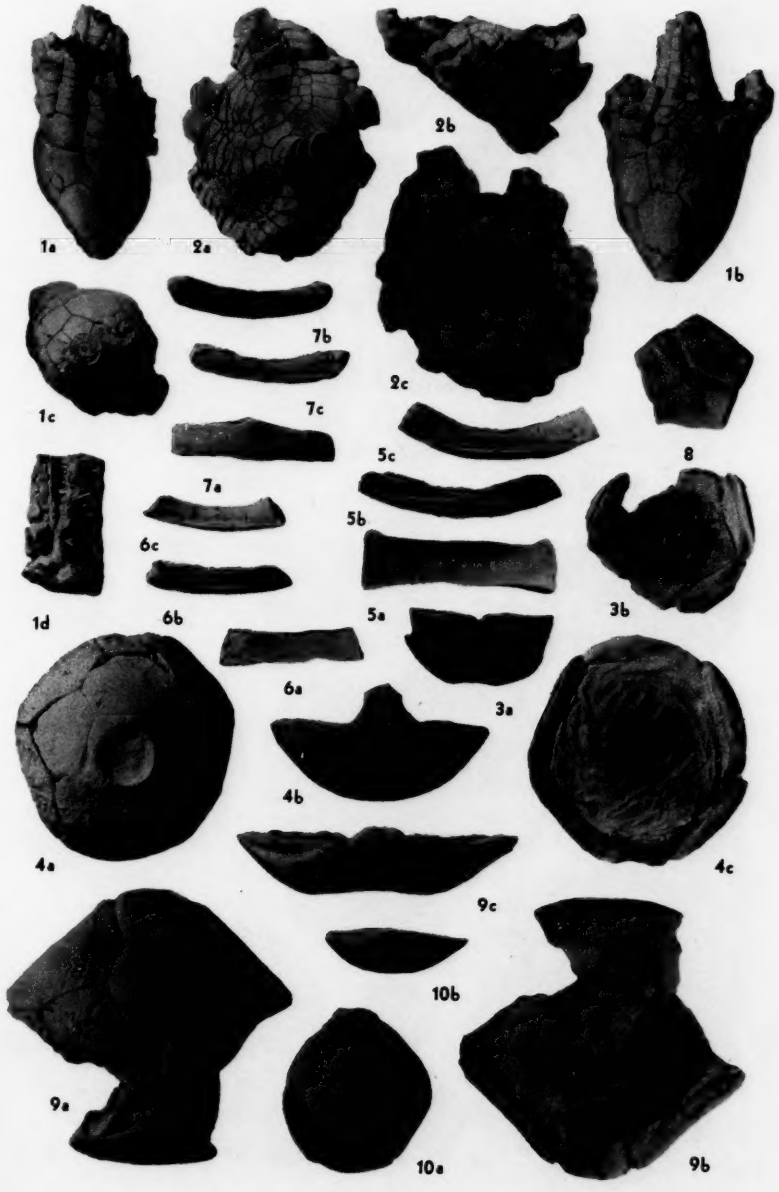
Graphiocrinus delicatulus, n. sp. 248

6—Holotype, a perfect dorsal cup, McGuire coll. (Kansas Univ. plastotype no. 45783); Brownville limestone, uppermost Pennsylvanian (Upper Carboniferous), 7 miles west of Strohm, Okla. *a*, Dorsal view, showing the very small but sharply defined basal concavity and the smooth contour of the cup (×2); *b*, ventral view, showing the subhorizontal facets equal to the width of the RR (×2); *c*, posterior view (×2).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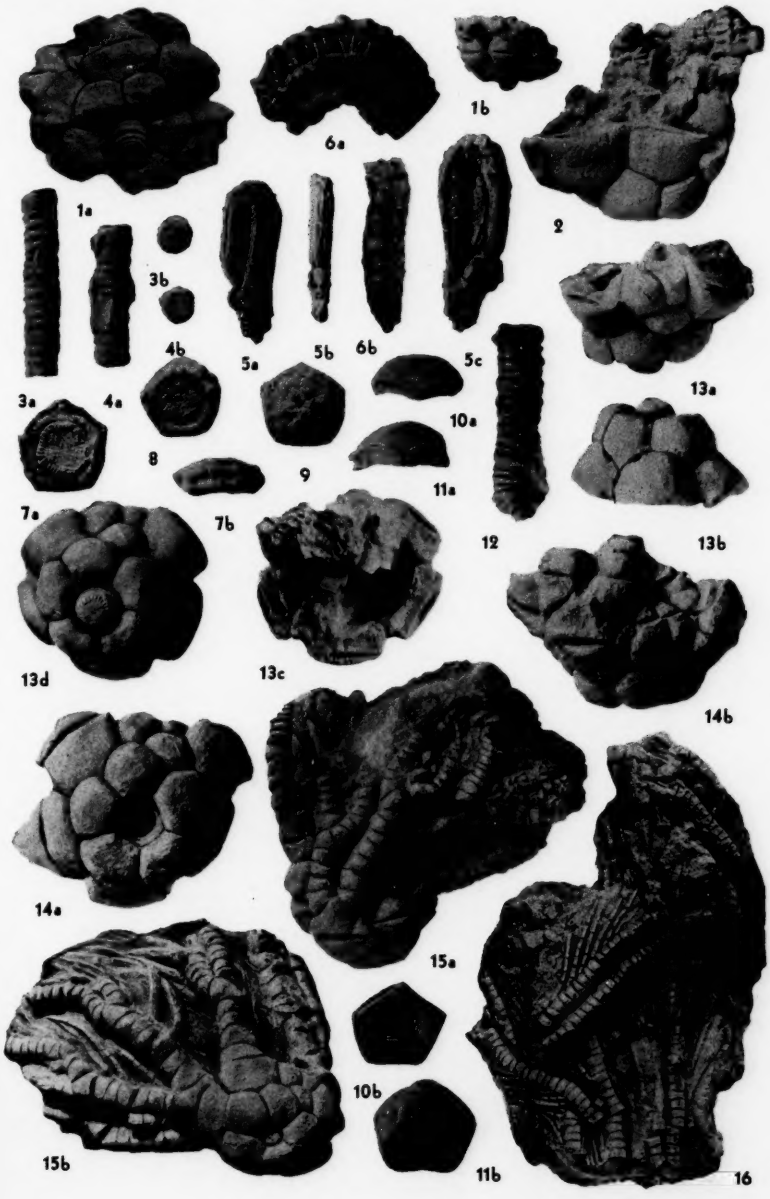
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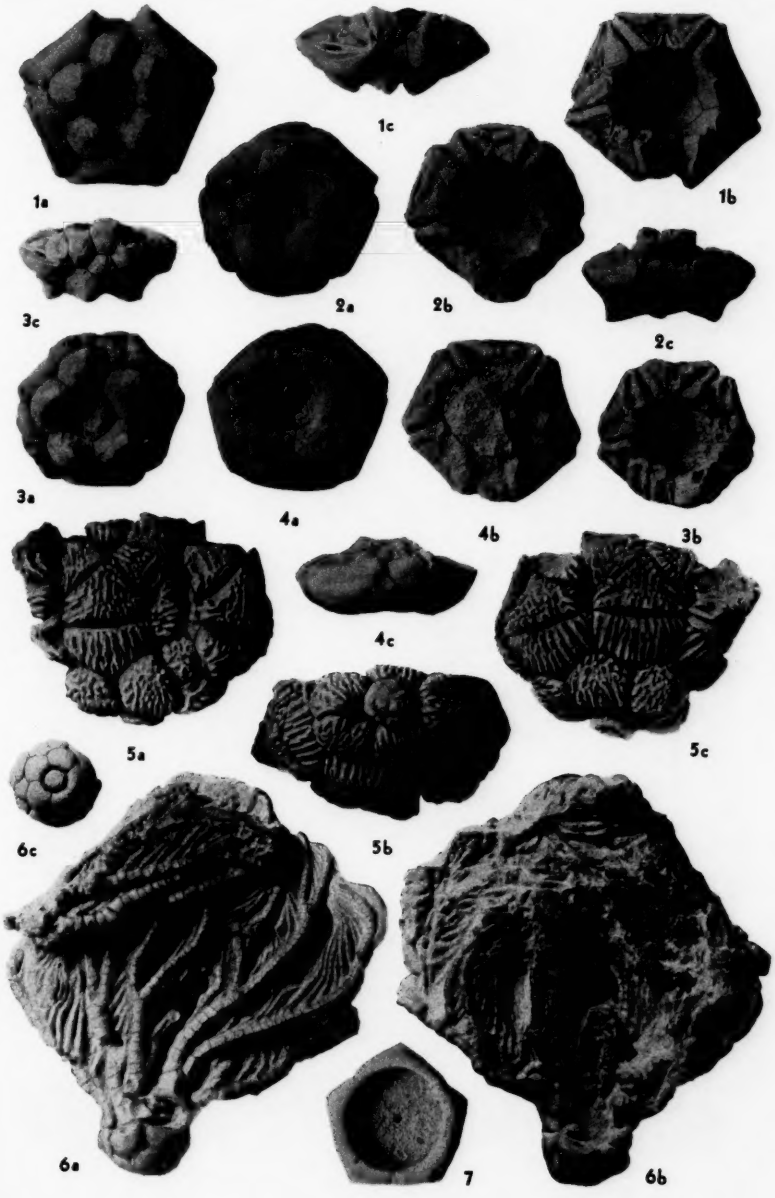
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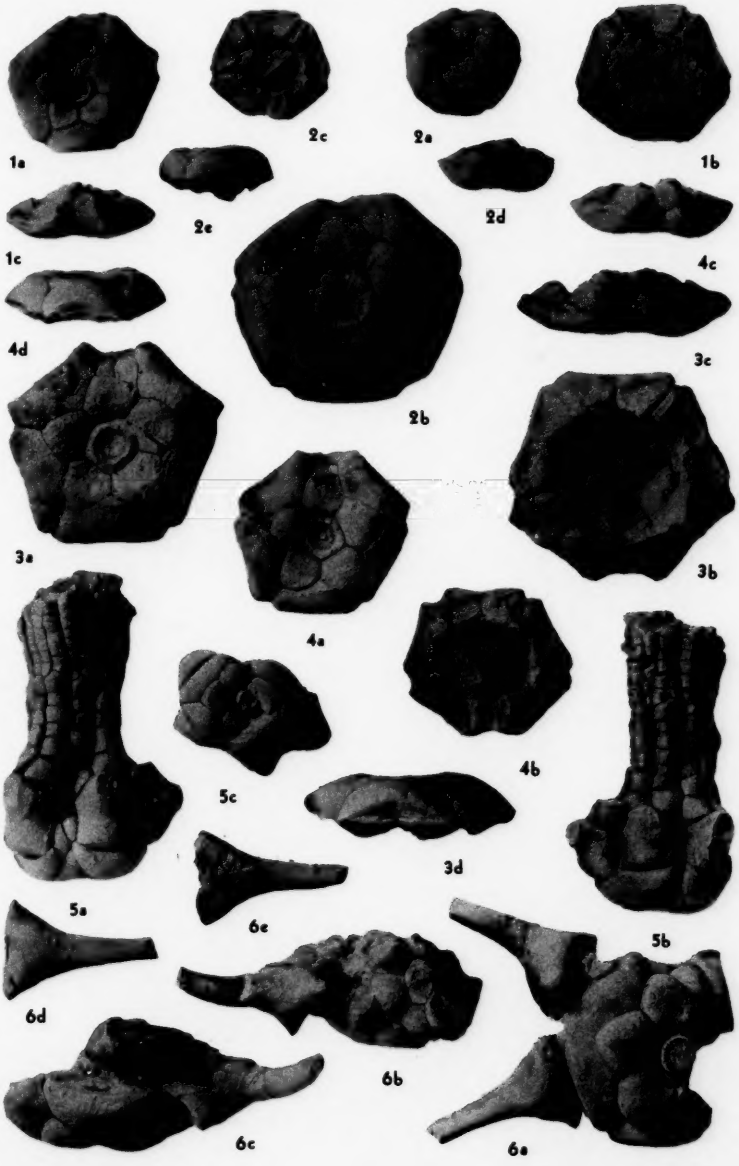
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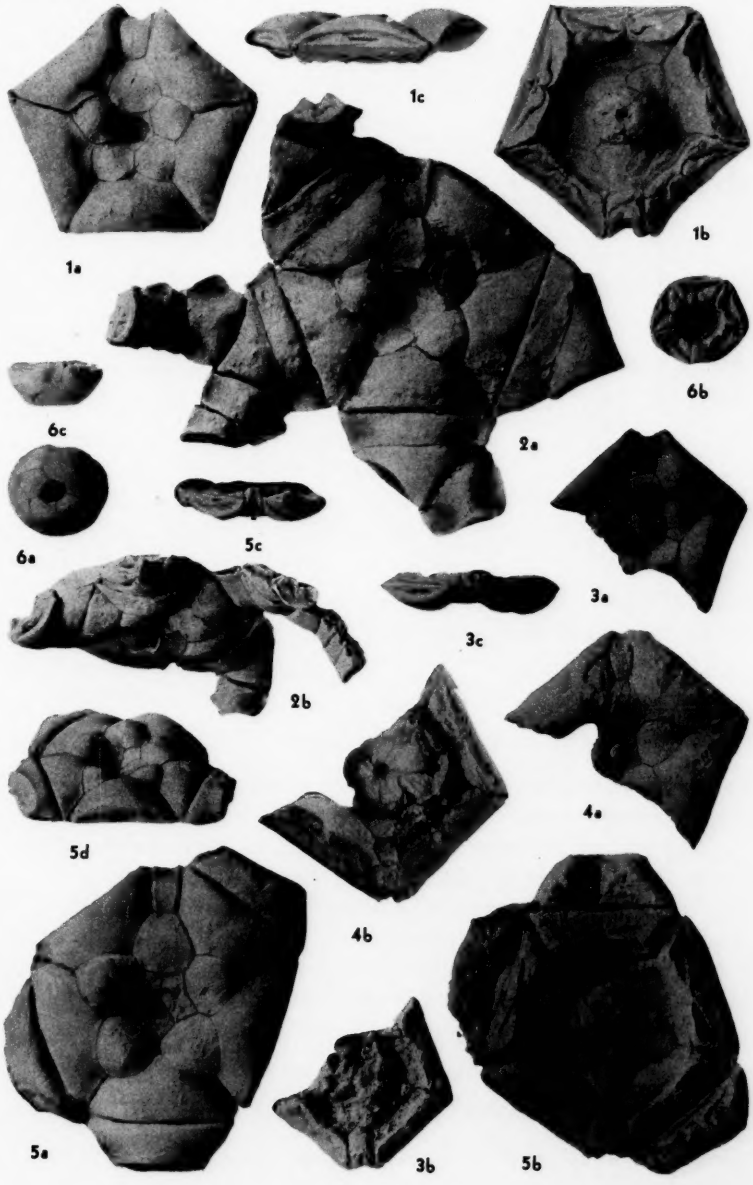
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DENISON SCIENTIFIC ASSOCIATION

Organized April 16, 1887

REPORT OF THE PERMANENT SECRETARY FOR THE YEAR 1938–1939

The following members served as officers during the current year:

CHARLOTTE RICE RODEN, *President*
A. C. LADNER, *Vice-President*
W. C. EBAUGH, *Permanent Secretary and Editor*
GEORGE D. MORGAN, *Recording-Secretary and Treasurer*
L. E. SMITH, *Librarian*

Meetings of the Association were held as follows in the lecture room of Barney Science Hall, except as indicated for three sessions, viz.:

October 4

RADIO TODAY. RICHARD H. HOWE (retiring President).

Increasing demands by new types of radio services for more frequencies in the radio portion of the electromagnetic spectrum have completely utilized all available practical frequencies.

A review of the public services utilizing the various frequencies was presented in broad outline, and the latest service offered to the public, television, was discussed in detail with respect to accomplishments in this field both in the United States and abroad. Lantern slides and demonstration equipment were used to illustrate the discussion.

October 18

THE AUTUMN PAGEANT. MALCOLM E. STICKNEY.

Nature provides many scenes to delight the eye of beauty-loving man. Although the wooded dell with its carpet of dainty

flowers is lovely, and the unbelievable blending of colors in the rocks of Bryce Canyon makes it a most gorgeous spectacle, nothing in nature is more impressive than the blaze of glory shown by a forest in autumn. What calls forth these brilliant colors? Why does one maple become red, another yellow, and a third purple? Why do the leaves of certain trees, or of certain branches of a tree, turn color sooner than the rest? Why is the autumn foliage so much more gorgeous in color some years than in others? Why does it last so much longer in some years than in others? What parts of the world are privileged to see this pageant in its glory while the rest of the world must needs forego this joy?

We are taught in the kindergarten that Jack Frost paints the trees. Is this true? What is the truth? An attempt was made to bring science's answer to the age-old question.

November 1

RECENT ADVANCES IN SOLAR INVESTIGATIONS.

FREEMAN D. MILLER.

During the last decade what additions have been made to our understanding of the sun? Theoretical astronomers and physicists are working together on the problem of explaining the continual release of heat and light by subatomic processes deep down in the sun's interior. Observational astronomers have adapted and extended the methods of laboratory physics to the examination of the seething surface of the sun, with its sun spots and gigantic prominences or flames. Radio engineers, meteorologists, biologists and even economists have looked for—and sometimes found—clear relationships between various types of solar activity and terrestrial phenomena in their respective fields.

Illustrating the subject motion pictures taken recently at the McMath-Hulbert Observatory of the University of Michigan were shown: the explosion of great hydrogen and calcium flames from the sun was depicted. The development of the technique of taking such pictures is one of the most significant recent advances in solar physics.

November 15

HEALTH FROM THE MENTAL ANGLE. T. A. LEWIS.

The maximum "a sound mind in a sound body" once played a desirable role, for the body certainly has more to do with health of the mind than do demons; but the "sound body" slogan eventually swung opinion so far toward the physical that the health program became one-sided again. The error in this medical maxim is found in the fact that mental health is a matter of adjustment, not simply to the condition of the body, but to a whole world of conditions. How one reacts when confronted by life situations which are sufficiently thwarting to take his measure shows how healthy he is mentally. Certain methods used to promote mental health, and to prevent or cure mental illnesses, were discussed.

November 29

A PERSONALLY CONDUCTED TOUR THROUGH THE FOURTH DIMENSION. F. B. WILEY.

Mathematics is a country through which but few travel. Fewer still travel and comprehend its sights. The reports brought back by these latter are often couched in terms not easily understood. Misinterpretation, misconceptions, and falsity arise. The Fourth Dimension, bearing a name that has caught the eye of the public, has suffered more than its share of false reports, and the attempt was made to interpret correctly and clarify such reports, and to keep an eye open for the practical side of even this ultra-theoretical subject.

December 13

MEXICO. H. C. SHETRONE (Ohio State University).

A lecture dealing with a recent visit to Mexico, and illustrated with the speaker's own photographic records. The ruins and monuments of civilizations that existed long before the coming of the white man, the life and culture of peoples now extinct, were revealed in a fascinating way. (Recital Hall).

January 10

HAWAII—LAND OF UNIQUE GEOLOGY. PARIS B. STOCKDALE (Ohio State University).

Impressions and observations gained during a recent visit to Hawaii, with particular reference to the geological features and physiography of the "Land of Sunshine," were related. Motion pictures made by the speaker added much to the interest of the story.

February 7

THE EFFECTS OF HYPNOTIC DRUGS ON LEARNING AND ADJUSTMENT. PAUL E. FIELDS (Ohio Wesleyan University).

The effects of phenobarbital and other non-habit-forming drugs upon some 300 rats used in making studies of form-discrimination, learning, and other types of animal behavior, were reported in some detail.

February 21

"pH"—THE SOUR NOTE. W. C. EBAUGH.

Among the cabalistic signs introduced into science during the last generation perhaps "pH" is used most frequently. That acids have a sour taste, contain hydrogen in a special easily separated form yielding an ion designated as "H^+," and can alter the colors of certain substances—called indicators—are facts known to students of elementary chemistry. But just *how* acid is a given solution momentarily in comparison with others of the same equivalent concentration? How can the sourness or acidity be measured, even in strongly alkaline solutions, whether the liquids be as colorless as water or like ink, dyestuffs, or animal or plant fluids? By demonstrations at the lecture table conducted by upper-classmen, and accompanying explanations, an attempt was made to show how the problem so essentially complicated in theory becomes relatively simple in practice. Some of the numerous applications of "pH" in pure and applied science and industry were emphasized. (Chemistry Cottage)

March 7

THE HOLLAND TUNNEL. A. COLLINS LADNER.

The Holland Tunnel, a double-tubed vehicular passage between Canal Street in Manhattan and Provost Street in Jersey City, is one of the world's greatest engineering feats. Built by the states of New York and New Jersey, it required more than seven years for construction and cost about fifty million dollars. It was opened for traffic November 13, 1927. Its two tubes lie 72 feet below the surface of the Hudson River; the northern one, for west-bound traffic, is 8,557 feet long, and the southern one, for east-bound traffic, has a length of 8,371 feet. The interiors are faced with white tile, brilliantly lighted, and ventilated by 84 huge fans. Policemen stationed at intervals on a catwalk along the walls supervise the movement of traffic. Nearly 12,000,000 motor passengers were carried through the Holland Tunnel in 1936. The lecture was well illustrated.

March 21

A SYMPOSIUM on ARE SOCIAL STUDIES A SCIENCE?

ARTHUR W. LINDSEY AND FREDERICK G. DETWEILER.

The question "Is psychology a science?" was the origin of this topic, but out of it grew the suggestion that all of the so-called social sciences might be in the same category. In the Denison University catalogue these subjects are wisely grouped under the heading "Social Studies," yet the other term persists. Is it justifiable? In attempting an answer to this question we come very close to a discussion of scientific method in general, and may well inquire to what extent is man successful in applying his scientific methods to the study of his own social relations. In so far as social studies remain factual, objective, and concern themselves with the orderly arrangement of knowledge in their fields they may claim to be following the scientific method, but when they interject sentimental, ethical and social bias into their investigations perhaps such a claim must be disallowed.

April 11

COLOR PHOTOGRAPHY. LEON E. SMITH.

The making of pictures in full and true natural color by anyone is an ideal not yet attained. There is hope that something like this may be accomplished, and much progress has been made, but so far stubborn unsolved problems face the investigator in the field of color photography. Various methods of operation were described, together with their underlying physical principles, the historical point of view serving as a guide. Illustrations of actual color photographs added to the interest of the demonstration.

April 22

PLASTIC SURGERY IN TRAFFIC TRAGEDIES. DR. CLAIRE LEROY STRAITH (Detroit, Michigan).

Traffic accidents, their causes and effects upon persons, and demonstrations as to what can be done by plastic surgery technique to remedy the facial and other disfigurements resulting from such accidents, formed the basis of an interesting presentation of this important phase of modern life. (Recital Hall)

April 25

TERRACES OF THE NEW RIVER. FRANK J. WRIGHT.

Stream terraces, produced by various geological processes, are common in many valleys of the Appalachian region. The types of terraces found—especially those of the New River—were described, and the later erosional history of the region explained upon the basis of findings concerning terraces. Color motion pictures were used for illustrations.

May 9

MODERN ARCHITECTURE. HORACE KING.

The Men: Henry Hobson Richardson (1838–1886) Louis Frank Sullivan (1856–1925) Frank Lloyd Wright (1868– ——)

The Meaning: The birthplace of modern architecture, con-

trary to the most widespread popular opinion, is our own middle west, specifically Chicago and St. Louis. The time of its birth was just a few years before the Columbian Exposition of 1893. A motivating cause was the successful introduction of Bessemer steel into building construction, with the guiding principle "Form follows Function"; no longer was it necessary to follow classic Greek and Roman post-lintel and arch systems. The last decade has brought us face to face with a new style of architectural forms, some good and some exceedingly bad, following more or less closely the teachings of Richardson, Sullivan, and Wright. Illustrations freely used emphasized this statement.

Three numbers of the JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY were published as follows:

Vol. XXXIII, Articles 2-3, pp. 61-155, August, 1938
- Chemistry and the Modern Meat Packing Industry; Minard Patrick, 48 pp., 3 figs.
- Certain Nuclear Masses in the Macaque Medulla Oblongata—Preliminary Report; Frederick David Goudie. 47 pp., 8 figs.

Vol. XXXIII, Articles 4-7, pp. 157-369, December, 1938
- The Use of Fragmentary Crinoidal Remains in Stratigraphic Paleontology; Raymond C. Moore, 86 pp., 14 figs., 4 plates.
- New Ostracodes from the Golconda Formation; Carey Croneis and Franklin A. Thurman. 34 pp., 2 plates.
- New Ostracodes from the Clore Formation, Carey Croneis and Harold J. Funkhouser. 29 pp., 2 plates.
- Report of the Permanent Secretary of the DENISON SCIENTIFIC ASSOCIATION. 8 pp.

Vol. XXXIV, Articles 1-3, pp. 1-63, April, 1939
- Some Factors Affecting the Operation of Incandescent Lamps; W. E. Forsythe, E. Q. Adams, and P. D. Cargill. 27 pp., 7 figs.
- Taxonomy of Chester Ostracodes; Carey Croneis. 4 pp.
- New Ostracodes from the Renault Formation; Carey Croneis and Ralph L. Gutke. 31 pp., 2 plates.

Requests for orders for back numbers of the JOURNAL now out of print continue to come in. It would be a favor to libraries and scientific institutions and workers in science were former members and friends to return to this office old copies no longer needed by them.

Securing finances to cover printing costs remains a serious

problem. In the annual report of the Permanent Secretary and Editor to the President of Denison University, it was suggested that persons interested in science, or who had profited from the applications of science, might like to make designated gifts in order that the publication of our JOURNAL at its high level of excellence might be continued. Unless such aid is forthcoming serious retrenchment will be necessary.

Respectfully submitted,

W. C. EBAUGH, *Permanent Secretary and Editor*

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